ANALYSIS AND FORECASTING OF U.S. NAVY OPERATING AND SUPPORT (O&S) COSTS FOR ROTARY AIRCRAFT

THESIS

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Abstract

This research explores forecasting techniques to estimate the Cost per Flying Hour (CPFH) for Navy rotary aircraft. Three separate forecasting techniques were evaluated to better predict the CPFH for estimating and budgeting purposes. The process begins by empirically analyzing Operating & Support cost categories for each helicopter. Trends were examined in CPFH. For forecasting purposes, actual CPFH figures were compiled from 1997 to 2003 for the CH-46D, the CH-53D, the MH-53E, the SH-60F, the UH-1N, and the UH-3H helicopters. The forecasting techniques explored include: the 3-year moving average, the single exponential smoothing method, and Holt's linear method. These forecasting techniques are used to forecast for FY03 in evaluating the best methodology to forecast the CPFH for FY04. By comparing both the budgeted and forecasted figures for FY00 – FY02 to the actual CPFH figures in the same years, CPFH was more accurately forecasted. Actual, budgeted, and forecasted CPFH were compared for FY03. Holt's linear method was deemed the best forecasting method for 67 percent of the time series analyzed. The analysis was based on summary statistics and calculations. Finally, FY04 CPFH was forecasted for each helicopter using the chosen forecasting method.

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Christopher J. Wilkes

Table of Contents

Page

Page

List of Figures

Page

Page

Page

List of Tables

Page

Page

Page

Page

ANALYSIS AND FORECASTING OF U.S. NAVY OPERATING AND SUPPORT (O&S) COSTS FOR ROTARY AIRCRAFT

I. Introduction

Background

Estimating the costs of operations and support (O&S) activities has become increasingly important in recent years due to shrinking budgets, aging aircraft, and the cost of maintaining newer, more technologically advanced weapon systems. O&S costs include "All personnel, equipment, supplies, software, services, including contract support, associated with operating, modifying, maintaining, supplying, training, and supporting a defense acquisition program in the DoD inventory" (1:49). O&S costs are one of the four main cost categories that constitute the life cycle cost of a weapon system. The other three cost categories are Research and Development (R&D), Investment, and Disposal. O&S costs constitute the majority of the total life cycle cost for aircraft as shown in Figure 1. Figure 1 represents the typical FY80 DoD acquisition program with a service life of about 30 years.

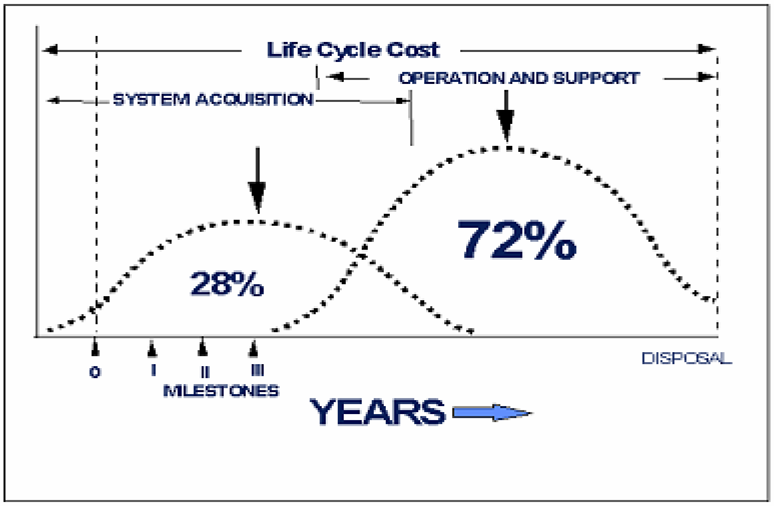

Figure 1. Nominal Cost Distribution

Controlling life cycle costs for weapon systems is a major issue for the Department of Defense (DoD). The military must do more with less. O&S costs are rising and have become a very large portion of the Navy's budget. Increases to O&S costs limit budget requests for new weapons systems development, modernization, and infrastructure. O&S costs consist primarily of operations and maintenance (O&M) and military personnel (MILPERS) appropriations. In an August 2001 report, the Congressional Budget Office (CBO) reported that approximately 37 percent of DoD's budget goes to support the O&M costs for military weapon systems (2:1). The costs will continue to rise as weapon systems become older and more antiquated.

Managers and cost analysts must pay increased attention to the trends in cost management. A view involving the total life-cycle cost must be adopted; an incomplete perspective that only includes the costs of development and production is no longer acceptable. More accurate estimating will lead to better budgeting, reduction in total ownership costs, and improved fiscal responsibility. As today's aircraft age, the cost of maintaining the equipment will increase to unprecedented levels. This research will examine O&S costs for Navy rotary aircraft in an effort to develop forecasts for future cost per flying hour (CPFH). The research conducted and model developed will prove valuable in the overall aim to reduce the Navy's total ownership costs of current and future rotary aircraft weapon systems.

Problem

A discrepancy has arisen in the past several years between submissions the services have provided in the Program Objective Memorandum (POM) during the out-years and the actual expenditures reported for CPFH programs. The Office of the Secretary of Defense/Cost Analysis Improvement Group (OSD/CAIG) requests the development of a measurement tool to analyze the validity of the services' submissions effectively. Forecasting models for CPFH are necessary for all aircraft within each service. The aim of this research will be to develop a model that accurately forecasts future CPFH for Navy rotary aircraft. The ultimate goal will be to give the OSD/CAIG a useful tool with which to compare the services projections against independent analyses in expectations of forecasting and possibly controlling future O&S costs.

Research Questions/Objectives

The following research questions and objectives are addressed in the body of the thesis:

1. Primary:

- To provide OSD/CAIG with a useful tool to forecast CPFH for Navy rotary aircraft.

2. Secondary:

- What are the major O&S cost drivers, by Major Claimant, for each weapons system?
- To what extent did the POM submissions deviate from actual CPFH figures in FY00-FY02?
- How do the forecasted figures of FY00-FY02 compare to the POM submissions and actual figures in the same years?
- For the weapons systems being studied, what are the forecasted CPFH for fiscal year (FY) 2004?

Summary of Current Knowledge

The services believe that the increase in total O&M costs is mainly attributable to the escalating costs for aging equipment (2:1). O&S costs consist of O&M plus the cost of military personnel. Therefore, escalating O&M costs would directly increase O&S funding levels. The aforementioned study conducted by the CBO indicates that increased O&M spending is not a direct result of aging equipment. O&M spending includes diverse cost categories such as costs for health care, environmental programs, real property maintenance, and base operating support. Although the report does not support the contention that the increase in O&M costs is due to aging equipment, evidence exists that aircraft become more costly to maintain as the aircraft age. For example, Navy aircraft spending could escalate by $40 million to $130 million per year in a yearly O&M

budget of $23 billion (2:2). Because O&M costs constitute a large portion of O&S costs, O&S CPFH will more than likely accelerate in the future.

The CBO study suggests average aircraft age has increased slightly over the past two decades. Cumulative O&M spending per hour has increased but not significantly so. The study differs from the services' perspective in that the services suggest that O&M costs for aging equipment are spiraling out of control. According to the CBO, only 20 percent of O&M spending is directly dependent on equipment. The report states, "CBO's findings are in conflict with the services' statements that spending on O&M for equipment is growing rapidly. Those statements are sometimes based on selective data" (2:9). The study indicates that aircraft, including rotary, are the only weapon systems that have increased in average age; however, none of the weapon systems have experienced notable O&M cost growth over the past couple of decades (2:8).

The CBO report surmises that costs for operating equipment may indeed increase as the weapon systems age but that cost may be paid for with other appropriations not including O&M funding. The sources that fund O&S costs include the following: operation and maintenance, military personnel, procurement, military construction, stock funds, and other appropriations (1:49). The rising costs could be attributed to higher personnel costs due to increased maintenance for modifications to equipment paid for with procurement funds (2:20). Thus, even though the CBO does not agree that weapon systems O&M costs are rising mainly due to aging equipment, the services' contention that O&S costs are rapidly increasing for aging equipment remains valid because O&S costs are funded by other appropriations besides O&M money.

More research needs to be conducted for cross-service studies to address cost growth and the relationship between cost growth and age. This thesis will address the O&S CPFH for rotary aircraft within the Navy. Trends over time will provide answers to whether or not CPFH has increased substantially by aircraft type and as a whole. Trends will be forecasted to provide the OSD/CAIG with a yardstick to measure against Navy rotary aircraft CPFH budget submissions for the POM out-years.

Scope and Limitations

This research will develop a forecasting model useful in predicting trends in CPFH for Navy rotary aircraft. At the same time, this research is being conducted similar research efforts will be conducted for the Army and Air Force. Hawkins examines the O&S CPFH for Army rotary aircraft. Laubacher investigates O&S CPFH for Air Force rotary aircraft. The results from all three theses will provide the OSD/CAIG with an effective tool to measure against the services' POM submissions and the results will give the OSD/CAIG a better understanding of the services' rotary aircraft CPFH.

Standards

In developing an accurate projection of future events, models must be constructed that utilize certain relationships inherent within a system. In the case of forecasting, historical data can be analyzed and relationships between time series data can be used to develop models that suggest increasing or decreasing trends. Certain standards will be utilized to obtain the best forecasting model. Chapter III will address standards such as mean error, variances, and other useful statistical performance measures.

Approach/Methodology

Each service tracks O&S costs for rotary aircraft. The Navy was the first service to implement a database responsible for presenting all O&S cost information for weapon systems. The Navy database is called the Visibility and Management of Operating and Support Costs (VAMOSC). The Army and Air Force created similar systems of their own for reporting O&S cost information. The Army's version of the VAMOSC is the Operating and Support Management Information System (OSMIS). The Air Force named their system the Air Force Total Ownership Costs (AFTOC) database. The VAMOSC system is used extensively to extract CPFH information for Navy rotary aircraft.

The VAMOSC database is used to sort cost information by rotary aircraft type and model for each year. The first step is to analyze the data to determine how the costs are broken out according to the cost element structure (CES) of O&S costs described in the O&S Cost Estimating Guide. The results indicate any trends in recent years. Additionally, the data identifies any components which significantly increase as a percentage of the overall cost. Changes in the CES cost composition are addressed to decide if the change is model specific or if the trend subsists in all models of rotary aircraft.

The next step involves collecting the CPFH for each of the rotary aircraft types for each year. The Navy VAMOSC database contains all rotary aircraft information during the years FY97-FY02. Determining trends within cost data is important in deciding what type of forecasting model to use. The data is compared to the POM submissions in the same year to show any variances that exists between the actual CPFH and the budgeted CPFH. After examining CPFH data, forecasting models are constructed and are compared to the actual CPFH to show any variances present. These variances will be compared to the budget variances.

The best overall model is selected in the final step of the research and employed in forecasting CPFH for rotary aircraft for FY04. The model will capture any trends within the cost data. The model will help defend the OSD/CAIG's position if a future disconnect arises between the services' submissions and OSD/CAIG's in-house estimates. The OSD/CAIG can compare its estimates to the model to decide if any revisions are needed in the current OSD/CAIG forecasting process.

Organization

This thesis is divided into five chapters. Chapter I provides background information on the importance of accurate O&S cost estimation. A brief description of the problem and research questions/objectives is given. Then, the scope, limitations, and methodology portions are introduced. Chapter II presents more detailed background information on O&S costs and CPFH. Past research is analyzed to provide the reader with a historic look at the important findings previously completed. Chapter III describes the methods used to answer the research questions presented. Chapter III provides the framework for carrying out the aforementioned objectives. The findings and results of this research are given in Chapter IV. The recommended forecasting model is also presented supported by charts, tables, and summary statistics. Chapter V provides a summary and conclusion based upon the analyses performed with recommendations for future research.

II. Literature Review

Chapter Overview

Chapter II provides background information for estimating Operating and Support (O&S) costs and the cost per flying hour (CPFH) program. It explains the regulations that dictate O&S cost estimating, describes the CPFH program, describes the mission and current Navy inventory of the helicopters studied, and finally, covers past research in this area. This literature review explains what is required by law and by the regulations governing O&S costs and the CPFH program. Chapter II also explains the origin and requirements of the Visibility and Management of Operating and Support Costs (VAMOSC) database used to forecast CPFH for the specific weapons systems studied.

Introduction

The life-cycle cost for a Major Defense Acquisition Program (MDAP) encompasses the combined costs for a weapon system from the Mission Need Statement (MNS) through disposal and deactivation. In recent years, decision makers within the Department of Defense (DoD) have increasingly emphasized the projection of realistic O&S costs. The initiative to estimate costs realistically results from escalating outflows for aging systems and the need for newer, more technologically sound weapons in an unprecedented era of rapid deployment and global terrorism. The ability to plan for precise life-cycle costs has become more crucial because of competition for scarce resources and increased scrutiny involving oversight of funds. O&S costs represent the largest portion of the total life-cycle cost.

Figure 2 illustrates a typical break-out of the life-cycle costs for a typical weapon system.

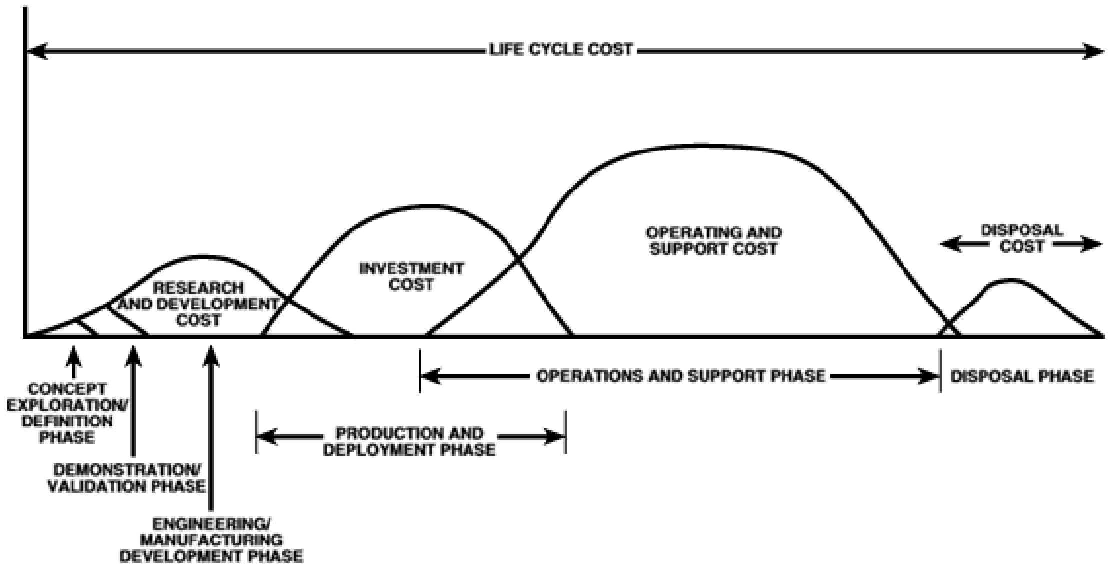

Figure 2. Program Life Cycle (Illustrative) [1]

The DoD will spend billions of dollars on force modernization in the post September 11 timeframe. Although the Bush administration has increased the defense budget, the military still faces an uphill battle to produce cutting edge technology. Military men and women must remain vigilant in all areas of defense budgeting. The cost analyst can make significant contributions by accurately forecasting O&S costs. The overall defense budget has shrunk since the Cold War and consequently, the military must do more with less. Table 1 shows the DoD Budget Authority by Appropriation figures for the total budget and the operations and maintenance (O&M) portion of the budget.

[1] Figure 2-1 is taken from the OSD CAIG *Operating And Support Cost-Estimating Guide* (3:2-2). The figure is used for illustrative purposes only. Actual program results may vary.

Table 1. DoD Budget Authority by Appropriation Table[2]

Fiscal Year	Current $ (Billions)	Constant FY03 $ (Billions)	O&M Current $ (Billions)	O&M Constant $ (Billions)	% of O&M Growth (FY03 Constant $)	O&M % of DoD Budget
1985	286.802	461.666	77.803	126.827		27.47%
1990	292.999	405.421	88.309	123.188		30.39%
1998	258.583	294.567	97.215	110.484	2.5	37.51%
1999	278.595	309.988	104.992	116.663	5.6	37.63%
2000	290.534	315.183	108.776	118.479	1.6	37.59%
2001	309.948	326.385	115.758	121.259	2.3	37.15%
2002	329.878	337.195	127.668	130.241	7.4	38.62%
2003	378.624	378.624	150.444	150.444	15.5	39.73%

In 1985, the DoD budget totaled approximately $462 billion (fiscal year (FY) 2003 constant-year dollars (CY)). The 1985 total exceeds FY03 by almost $84 billion. The overall budget has decreased in terms of FY03 CY dollars from 1985 to 2003, but the amount of O&M funding has increased during this period. O&S costs consist mainly of O&M and military personnel (MILPERS) appropriations. The percentage of O&M funding out of the total budget increased from 27.5% in 1985 to nearly 40% in 2003. The percent of real cost growth in O&M funding increased 15.5% from 2002 to 2003. Thus, O&M has become a substantial part of the defense budget. Therefore, accurate predictions for O&M cost estimates, including O&M estimates for CPFH, are imperative. Figure 3 depicts the budget trends graphically. The DoD total budget exhibits an upward trend but increases at a slower pace during the 1980s. O&M costs show a steady increase in the overall trend.

[2]Actual results taken from the Appendix A budget tables from Donald H. Rumsfeld's Annual Report to the President and the Congress (4:163).

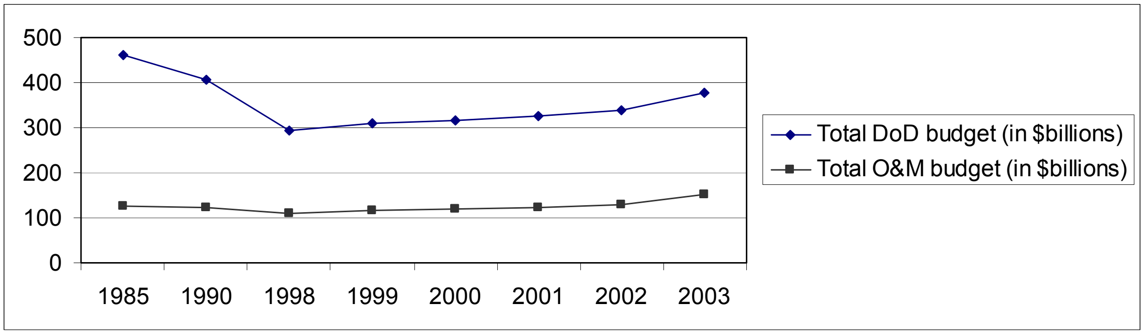

Figure 3. DoD Annual Budget and O&M Funding

When looking at the initial cost of procuring a weapon system, one must not focus solely on the cost to produce the weapon system, but must instead look at the entire spectrum of costs. The sustainment portion of the life-cycle cost constitutes the major apportionment of funding. This thesis concentrates specifically on examining the CPFH distribution of O&S costs for Navy rotary aircraft. Figures 4 through 9 depict the rotary wing aircraft within the Navy arsenal, followed by a brief description of each helicopter. The V-22 and TH-57 will not be included in this research. The VAMOSC database does not contain enough information to support analyses of these models. Forecasting tools will be applied to predict O&S CPFH for Navy rotary wing aircraft. The projections will serve the cost estimating community at the OSD/CAIG level with more defined CPFH data. The OSD/CAIG analysts will then possess the tools to identify any discrepancies with future estimates provided in the program objective memorandum (POM) estimates submitted by the services.

Rotary Wing Aircraft

Figure 4. The CH-46 Sea Knight Helicopter (5)

Figure 4 shows the CH-46 Sea Knight helicopter. The Sea Knight is described as a "medium lift assault helicopter, primarily used to move cargo and troops" (5). The helicopter was originally acquired in 1964 to meet the medium-lift requirements set forth by the Marine Corps. The Navy uses the CH-46D for shipboard delivery of cargo and personnel. The Marine Corps uses the CH-46E model as an all-weather, day-or-night assault vehicle for transporting combat troops, supplies, and equipment.

Figure 5. The CH-53D Sea Stallion Helicopter (5)

Figure 5 depicts the CH-53D Sea Stallion helicopter. The Sea Stallion is described as a medium lift helicopter used for transportation of personnel, supplies, and equipment in support of amphibious and shore operations. The helicopter was originally acquired in the 1960s to fulfill the Marine Corps requirement for a heavy lift helicopter. The CH-53E Super Stallion has since replaced the CH-53D as a heavy lift helicopter. The MV-22 Osprey will eventually replace both the CH-53D and the CH-46E. Two General Electric turbo shaft power the helicopter.

Figure 6. The MH-53E Sea Dragon Helicopter (5)

Figure 6 shows the MH-53E Sea Dragon helicopter. The Sea Dragon is described as a multi-engine helicopter, used primarily for Airborne Mine Countermeasures (AMCM). The secondary mission includes shipboard delivery. The Sea Dragon was originated from the CH-53E Super Stallion and is heavier and possesses greater fuel storage capacity than its predecessor. The aircraft can also carry up to 55 troops or a 16-ton payload 50 nautical miles.

Figure 7. The SH-60 Sea Hawk Helicopter (5)

Figure 7 shows the SH-60 Sea Hawk helicopter. The Sea Hawk replaced the SH-3H Sea King as the premier anti-submarine warfare helicopter. The Sea Hawk supplanted the Sea King in the mid 1990s. It is a twin-engine, medium lift, utility or assault helicopter. The Army version is the UH-60 Black Hawk. The Air Force model is the MH-60G Pave Hawk. The rotary aircraft is also used for "search and rescue, drug interdiction, anti-ship warfare, cargo lift, and special operations" (5). The SH-60B model is used by the Navy as "an airborne platform based aboard cruisers, destroyers, and frigates, and deploys sonobouys (sonic detectors) and torpedoes in an anti-submarine role" (5). The only difference between the SH-60B and the SH-60F is that the SH-60F is carrier based.

Figure 8. The HH/UH-1N Iroquois Helicopter (5)

Figure 8 shows the HH/UH-1N Iroquois helicopter. The Iroquois is primarily used as a utility helicopter. The helicopter's main mission includes "airborne command and control, combat assault, medical evacuation, maritime special operations, supporting arms control and coordination, fire support, and security for forward and rear area forces" (5). The Iroquois is described as the most widely used helicopter around the globe. More than 9,000 Iroquois were produce since the 1950s. Forty countries make use of the Iroquois.

Figure 9. The H-3 Sea King Helicopter (5)

Figure 9 shows the H-3 Sea King helicopter. The Sea King is described as a twin-engine, multi-purpose helicopter. The helicopter went operational in June 1961. The SH-3H model is used by the Navy Reserves to "detect, classify, track, and destroy enemy submarines" (5). Additionally, the aircraft gives logistical support and handles search and rescue missions. The VH-3D model is used in the Executive Transport Mission.

History of the O&S Initiative

The DoD realizes the significant impact of O&S costs on its budget. The first efforts to track and control these costs began with the VAMOSC project in 1975 (6:1). This initiative was prompted by the Management By Objective (MBO) 9, with the stated goal of reducing O&S costs within the DoD (6:1). MBO 9-2, a subset of MBO 9, pointed out that historically, DoD components did not include O&S costs as a major factor in the acquisition of a new weapon system (6:1). The costs of maintaining current weapon systems should be identified and analyzed in order to estimate costs of new systems under consideration. The purpose of MBO 9-2 was to define the total costs associated with the acquisition and fielding of a weapon system within the different branches of the armed services (6:1). The objective divided the total Life Cycle Cost (LCC) of a system into two main categories: acquisition costs and ownership costs (6:2). The ownership costs, known collectively as O&S costs, were the area for concern and what most interested the DoD. Figure 10 shows the total ownership cost composition for aircraft.

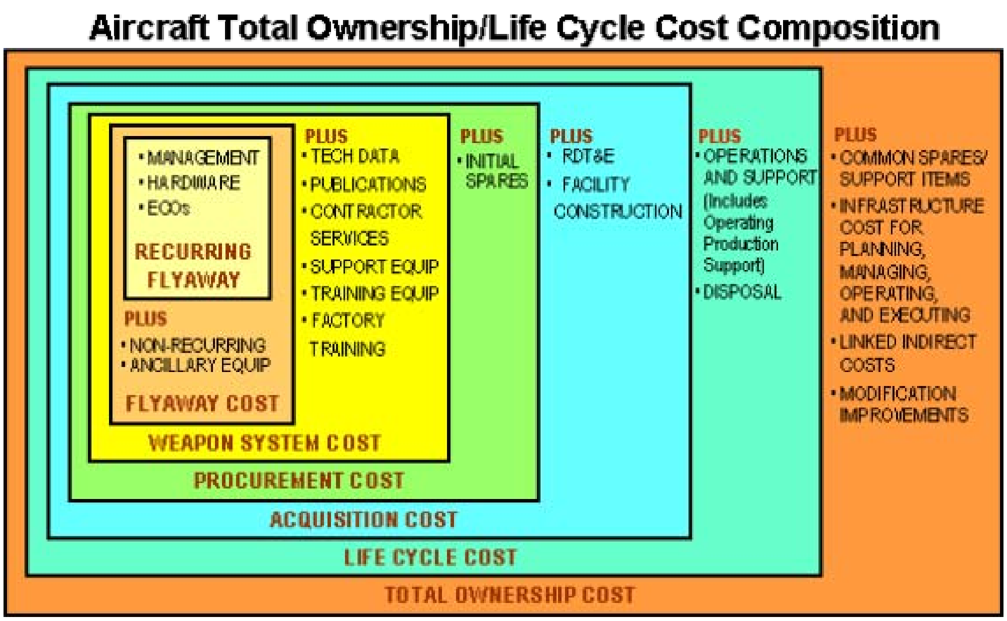

Figure 10. Aircraft Total Ownership/Life Cycle Cost Composition (7)

Since the establishment of MBO 9-2, "DoD policy requires the explicit consideration of O&S costs from the beginning of the acquisition process throughout the operational life of a program" (1:53). The OSD VAMOSC program was created to fill the need for O&S tracking within DoD. The Air Force responded to the initiative with the development of the Air Force Total Ownership Cost (AFTOC) database. The Army followed with the Operating and Support Management Information System (OSMIS).

The Office of the Secretary of Defense/Cost Analysis Improvement Group (OSD/CAIG) is responsible for executive oversight of each service's O&S database according to DoD regulation 5000.4-M. The regulation requires each DoD component to establish and maintain a database consisting of historical O&S data for all weapon systems in its inventory (1:53). "VAMOSC data shall be used as a basis for decisions concerning affordability, budget development, support concepts cost tradeoffs, modifications, and retention of current systems" (1:53). The OSD/CAIG promotes standardization of data collection by DoD components and provides a means for exchange of ideas between the different components in order to improve the use of the VAMOSC data (1:55). The CAIG also provides guidance on improving analytical methods for using O&S data.

Major O&S Guidance

This section explains the legal requirements of O&S estimating and reporting, as well as the requirements of O&S estimating provided in DoD directives and guidance. It also provides the background of the current DoD and Navy O&S reporting program. This section summarizes these regulations; it is not intended as a substitute.

Title 10.

United States Code Title 10 Section 2434 states:

> The Secretary of Defense may not approve the system development and demonstration, or the production and deployment, of a major defense acquisition program (MDAP) unless an independent estimate of the full life-cycle cost of the program and a manpower estimate for the program have been considered by the Secretary (8).

The Secretary of Defense shall prescribe regulations governing the content and submission of these required estimates (8). The regulations shall require that the independent estimate of the full life-cycle cost of a program include all costs of development, procurement, military construction, and operations and support without regard to funding source or management control (8). The regulation shall also require that the manpower estimate include an estimate of the total number of personnel required to operate, maintain, and support the program upon full operational deployment; and to train personnel to carry out these activities (8).

DoD 5000.4-M – O&S Costs.

> DoD Instruction 5000.2 and DoD 5000.2-M require that both a program office estimate (POE) and a DoD Component cost analysis (CCA) estimate be prepared in support of acquisition milestone reviews. As a part of this requirement, DoD 5000.2-M specifies that the DoD Component sponsoring an acquisition program establish, as a basis for cost-estimating, a description of the salient features of the program and of the system being acquired. This information is present in a Cost Analysis Requirements Description (CARD) (1:8).

The following sections of the CARD impact O&S costs:

- System Reliability
- System Maintainability
- Hardware Support Concept
- Software Support Concept
- Supply
- Training
- System Manpower Requirements
- Operation Support Facilities

One of the seven cost terms standardized by DoD 5000.4-M is O&S costs.

> O&S costs include all personnel, equipment, supplies, software, and services, including contract support, associated with operating, modifying, maintaining, supplying, training, and supporting a defense acquisition program in the DoD inventory. This includes costs directly and indirectly attributable to the specific defense program; i.e., costs that would not occur if the program did not exist (1:48).

The DoD 5000.4-M lists these O&S categories:

- Mission Personnel
- Unit Level Consumption
- Intermediate Maintenance
- Deport Maintenance
- Contractor Support
- Sustaining Support
- Indirect Support (1:48-49)

These O&S categories are currently (2003) in review and will be brought up to date with the new structure described in the Operating and Support Cost Estimating Guide from the OSD/CAIG draft dated July 31, 2003.

O&S Cost Estimating Guide.

The O&S Cost Estimating Guide provides a cost structure to be established as a guide to assist DoD cost analysts develop and present the results of operating and support cost analyses (9:1). The OSD CAIG O&S cost structure categorizes and defines cost elements that cover the full range of O&S cost that should occur in any defense system (9:1). The O&S cost element structure is divided into six major categories:

- Unit Personnel
- Unit Operations

- Maintenance
- Sustaining Support
- Continuing System Improvements
- Indirect Support (9:2)

The Unit Personnel element includes the costs of all operator, maintenance, and support personnel at operating units (9:2). Unit Personnel include active and reserve military, government civilian, and contractor personnel costs (9:2). Unit Personnel Costs are intended to include direct costs (i.e., costs of individuals assigned at installations that own the system and that can be clearly associated with the system performing its intended defense mission) (9:3).

Unit Operations includes the unit-level consumption of operation materials such as fuel, petroleum, oil, and lubricants (POL), electricity, expendable stores, training munitions and other operating materials (9:5). Also included are any unit-funded support activities; training devices or simulator operations that uniquely support an operational unit; temporary additional duty/temporary duty (TAD/TDY) associated with the unit's normal concept of operations; and other unit funded services (9:5). Unit-funded service contracts for administrative equipment as well as unit-funded equipment and software leases are included in this portion of the estimate (9:5).

Maintenance includes the costs of labor above the organizational level and materials at all levels of maintenance in support of the primary system, simulators, training devices, and associated support equipment (9:7). All maintenance costs provided through a system support contract will be separately identified within the appropriate cost element (9:7).

Sustaining support includes support services provided by centrally managed support activities not funded by the units that own the operating systems (9:10). It is intended that costs included in this category represent costs that can be directly tied to a specific system and exclude costs that must be arbitrarily allocated (9:10).

Continuing System Improvements includes the costs of hardware and software updates that occur after deployment of a system that improve a system's safety, reliability, maintainability, or performance characteristics to enable the system to meet its basic operational requirements through out its life (9:12). These costs include government and contract labor, materials, and overhead costs (9:12). Costs are required to be separated into government and contactor costs within each cost element (9:12).

The Continuing System Improvements portion of an O&S estimate does not include all changes to a system developed subsequent to the initial delivered configuration (9:12). System improvements identified as part of a pre-planned product improvement program that are included in the acquisition cost estimate are not included in this portion of an O&S cost estimate (9:12). Improvements designed to be incorporated in production lots (e.g., design series, block changes) and improvements that would qualify as distinct MDAPs are not typically included in this portion of the O&S cost estimate (9:12-13).

Indirect Support costs are those installation and personnel support costs that cannot be directly related to the units and personnel that operate and support the system being analyzed (9:13). The three levels of Indirect Support include Installation Support, Personnel Support, and General Training and Education (9:14-15).

DoD 5000.4-M - Establishment of VAMOSC.

Chapter 4 of the DoD 5000.4-M lays the foundation for the VAMOSC program. The purpose of the VAMOSC program is to achieve visibility of O&S costs; the DoD components are required to establish a historical data collection system and maintain a record of O&S data that facilitate the development of a well-defined, standard presentation of O&S costs by MDAP (1:53).

The objectives of the VAMOSC system are to provide visibility of O&S costs for use in cost analysis of MDAPs and force structure alternatives in support of the Programming, Planning, and Budgeting System (PPBS) process and satisfy the Congressional requirement that DoD track and report O&S costs for major acquisition programs (1:53). VAMOSC is also to provide visibility of critical maintenance and support costs at the subsystem level in sufficient detail to promote cost-conscious design and configuration management of new and fielded defense programs (1:54). VAMOSC is to provide visibility of O&S costs so they may be managed to reduce and control program life-cycle costs (1:54). Finally, VAMOSC is to improve the validity and credibility of O&S cost estimates by establishing a widely accepted database, thereby reducing the cost and time for collecting these defense program O&S costs for specific application (1:54).

The OSD/CAIG is charged with executive oversight of VAMOSC (1:55). In this capacity the OSD/CAIG shall promote standardization of O&S cost data collection by the DoD Components, provide a forum for the exchange of ideas among the DoD Components, and promote the effective use of VAMOSC data in predicting future costs (1:55).

The Naval Center for Cost Analysis and the VAMOSC System

In October 1992, the Department of the Navy (DoN) tasked the Naval Center for Cost Analysis (NCCA) with management and control of the VAMOSC system. The NCCA is the Navy component of the service cost centers responsible for working independent cost estimates (ICE) for MDAPs (10:6). In addition to maintaining the VAMOSC system, the NCCA leads the DoN cost community in issues of cost policy and policy implementation (11). The duty of maintaining the VAMOSC system enables the collection of data from over 125 financial and non-financial sources.

The VAMOSC system functions as the Navy's web-enabled version of the O&S database consisting of all of the historic costs associated with all of the Navy major defense acquisition programs. The database is unique in that it operates as the only database that tracks complete Navy aircraft O&S costs on a Type/Model/Series (T/M/S) basis. The VAMOSC system presents actual dollars spent, not the amount predicted or budgeted. The database reports cost information on 67 Aircraft T/M/S from fiscal year 1997 through fiscal year 2002. The following paragraphs will discuss the aviation database portion of the VAMOSC, as it serves is the basis for all data collected and reported in this thesis.

The VAMOSC aviation database separates into four separate components of cost information. The first component, the Aviation Type/Model/Series Report (ATMSR) database, contains aviation T/M/S data for FY86 through FY96. The second component represents the same aviation format but contains aviation T/M/S data for FY97 through FY02. According to the VAMOSC website, "The ATMSR used to be one database, but it was split into two after NCCA was able to obtain and reprocess many of the cost elements (particularly the manpower costs). It was split at 1997 because most of the reprocessing applied to data 1997 and later" (12). More detail and consistency has been implemented into the FY97-FY02 database through a re-collection of source data. The FY97-FY02 ATMSR database is used in the analysis because more consistent processing rules were applied that were not incorporated in the FY86-FY96 ATMSR database. Seventeen different data providers submit cost information into the ATMSR database. The VAMOSC database is further broken down into Naval Aviation Subsystem Reporting (NAMSR) and NAMSR+ components. The NAMSR component data consists of detailed maintenance data.

This thesis examines the VAMOSC ATMSR database to obtain the composition of costs for rotary wing aircraft. The database will aid in breaking down the costs attributed to each component of the CES. The major cost drivers for rotary wing aircraft can then function as a foundation for identification of forecasting techniques applicable for future trends. The ATMSR database contains information on 1,292 rotary wing aircraft (over 24 different T/M/S). Figure 11 shows the composition of the VAMOSC aviation database.

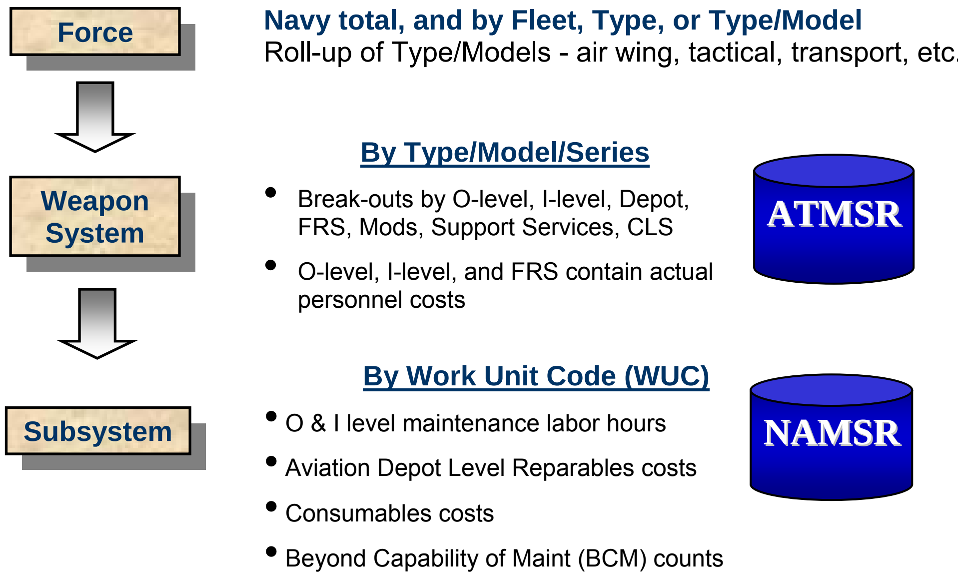

Figure 11. Aviation Database Composition (12)

Figure 11 demonstrates how the ATMSR and NAMSR fit into the overall VAMOSC system. NAMSR is a subsystem of ATMSR. ATMSR is a subsystem of the total force structure.

One purpose behind the creation of the VAMOSC system is to give analysts the tools to develop accurate O&S estimates for future weapon systems. The system grants visibility into the total O&S costs associated with each weapon system. Analysts now have an easier way to utilize statistical methods in building cost estimating relationships among major cost drivers in assessing future costs for new programs. The research in this thesis investigates O&S CPFH for rotary wing aircraft in the expectation that OSD/CAIG decision makers will gain a measurement tool to evaluate the accuracy of POM service inputs for CPFH. The end result will give the OSD/CAIG a reasonable forecasting tool for comparison against future CPFH costs reported by the Navy for rotary wing aircraft.

Past Research

Background of the Cost per Flying Hour Program- U.S. Air Force.

The Cost per Flying Hour program is a subset of the O&S portion of a budget submission. The Air Force program consists of three model-driven factors: (1) consumable supplies (both General Support and System Support Divisions); (2) depot-level reparables (DLRs); and (3) aviation fuel (AVFUEL) (13:4).

- **Consumable supplies** include aircraft parts and supplies that are not repaired and are discarded after use (13:4-5).
- **Depot-level reparables** are aircraft parts that are removed by maintenance personnel and sent to a depot for repairs (13:5).
- **AVFUEL** is fuel used during flight (13:5).

The cost associated with the Air Force flying hour program is calculated by using the CPFH metric (13:4). "Flying hours are the basic element for measuring aircraft usage to train aircrews for wartime taskings" (13:4). Each year in the November/December timeframe, the major commands (MAJCOMs) must submit recommended CPFH rates for each weapon system that will be included in the CPFH program (13:6). A separate factor for consumables, DLRs, and AVFUEL will be included in the submission (13:6).

The CPFH development begins by creating a baseline rate using the most recent year-end totals for obligations and flying hours (13:6). "Year-end obligations corrected for one-time obligations divided by hours flown develop the baseline CPFH" (13:6).
The next step involves adjusting the approved factors due to economic conditions, such as inflation/deflation (13:6). Major commands also review the factors and adjust them to

account for anything that will affect the CPFH, such as forecasted changes in policy, special programs starting, or changes in the level of maintenance (14:8-9).

At the same time, the Air Force Working Capital Fund (AFWCF) updates the budget and rates for all the AFWCF products, which includes DLRs and consumables, a major part of the CPFH expense (14:7). The CPFH factors are adjusted according to price changes forecast by managers of the AFWCF (14:10). Finally, the factors are used to fund flying hour programs in Air Force's POM, the Budget Estimate Submission (BES), and the President's Budget (PB), as well as the Financial Plan's initial distribution to the MAJCOMs (13:7).

"The Air Force Working Capital Fund was created in 1996 by the Under Secretary of Defense (Comptroller) as a reorganization of the Defense Business Operations Fund" (14:10). The AFWCF is a revolving fund that sells items necessary to support troops, weapon systems, aircraft, communications systems, and other military equipment (14:10). DoD Financial Management Regulation 7000.14R requires that the prices established by the AFWCF at the beginning remain stable for the remainder of the fiscal year (14:10). This stability allows analysts to use the cost factors previously calculated to budget more accurately for the flying hour program. For FY96 and FY97, the AFWCF was unable to establish accurate price lists for the repairable parts and consumable items that it supplied to Air Force flying units. After budgets were submitted and approved, prices for repairable parts and consumables were raised to the point that the MAJCOMs feared they would not have enough money to complete their flying hour programs (14:12). This price increase forced the Air Force to request supplemental funding to correct the projected shortfall (14:12). The AFWCF price instability has been known for some time and efforts to correct it are currently in progress (14:14).

The Army follows a similar method for computing factors used in the CPFH budget estimates. Cost factors are calculated by major command and by system based on historical data from the last three fiscal years. Demand for parts and flying hours for the system are averaged over the three-year period to obtain an average demand and flying hour for the system. The average demand for parts is multiplied by the updated parts price in effect for the upcoming fiscal year and this product is divided by the average hours flown over the three-year period (15:10).

Trends in Weapon System Operating and Support Costs.

This 1997 study focuses on the weapons systems and mission area that are responsible for force structure-related O&S cost increases. Two portions of this study that are of particular interest to this are the Department and Mission Category Analyses, and the Weapons System Case Studies. The Department and Mission Category Analyses compare O&S costs for FY75, FY85, and FY95 for the DoD as a whole, the services, and for selected major mission categories. The analyses analyze the results with respect to changes in equipment levels, activity rates, capability, age, and asset value (16:3). The weapons System Case Studies compare O&S costs for the same years at system-class level in selected mission categories as case studies (16:3). The Future Years Defense Program (FYDP) database was used as the primary source of O&S cost data for the Department and Mission Category Analyses. The Weapons System Case Studies the O&S cost data was drawn from each services VAMOSC database (16:4-7).

This study begins by examining O&S cost growth for the department and services during the FY75 to FY95 period. When the data is normalized to FY75, the O&S cost of the DoD grew four percent, Navy grew two percent, Army declined six percent, and the Air Force declined thirteen percent (16:8). These figures are a combination of substantial reductions in military personnel costs and substantial increases in O&M costs (16:8). For the same period, DoD O&M costs grew by 36 percent, the Army by 31 percent, the Navy by 23 percent, and the Air Force by 11 percent (16:8).

After a brief methodology explaining the charts used, the study focuses its attention on the different services starting with the Department of the Army. The review of this study focuses on the Department of the Army, since the Army analysis includes helicopters. Sections covering the Navy and Air Force exclude helicopters from the analysis of O&S costs.

The Army experienced a six percent decrease in O&S costs from FY75-FY95; at the same time, O&M costs rose by 24 percent (16:1). In the Mission Category review of the Army, the study includes Attack Helicopters, Observation Helicopters, and Utility Helicopters.

Table 2. Attack Helicopter Data (In Constant-Year FY96 Dollars)

Data Element		FY75	FY85	FY95
Aircraft		766	1,140	1,393
O&M ($M)		205	326	527
Hours		133,046	201,898	236,370
Asset Value ($M)		2,920	4,599	11,248
TASCFORM		1,538	2,655	6,754
Average Age		5	11.5	13.5
Flying Hours Per Aircraft		174	177	170
O&M Per Aircraft ($K)		268	286	378
O&M Per Flight Hour ($)		1,544	1,613	2,228
O&M Per $10K Asset Value ($)		703	708	468
O&M Per Capabiity Unit ($K)		134	123	78
Equipment Data	AH-1E		97	23
	AH-1F	352	501	490
	AH-1G	31	11	3
	AH-1P	2	95	10
	AH-1S	381	389	121
	AH-64A		47	746

Attack Helicopters.

For Attack Helicopters, Table 2 and Figure 12 show that between FY75 and FY95:

- The total number of aircraft increased 82 percent while flying hours increased by 78 percent,
- There was a 157 percent increase in total O&M,
- Asset value increased by 285 percent and mission capability increased by 339 percent (16:8).

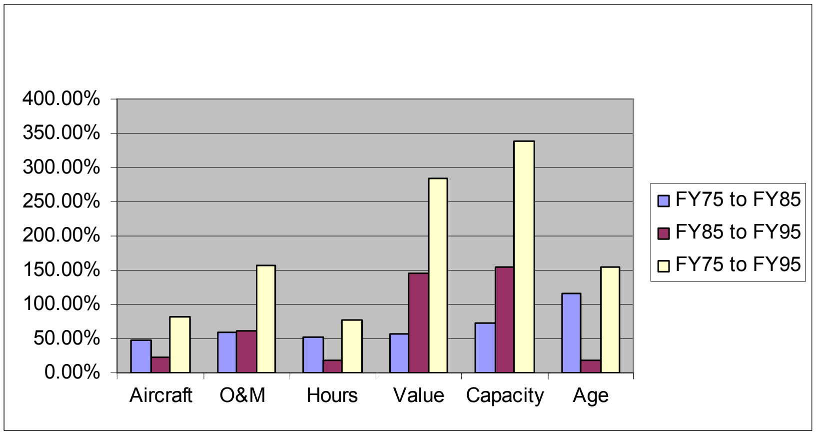

Figure 12. Attack Helicopters

The per unit section of Table 2 and Figure 13 show that between FY75 and FY95 O&M cost:

- Per aircraft increased by 41 percent,
- Per flying hour increased by 44 percent,
- Per $100K of Asset Value dropped by 33 percent, and
- Per unit of capability dropped by 41 percent (16:8).

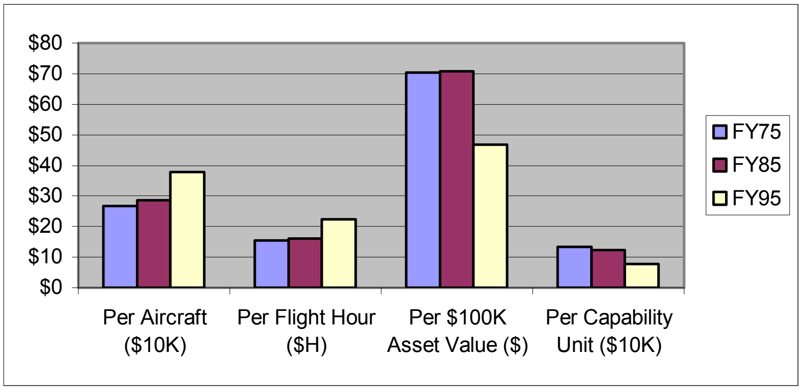

Figure 13. Attack Helicopter O&S Cost Ratio Changes

During the FY75-FY95 there was a marked increased modernization of attack helicopters (16:10). Table 3 focuses on attack helicopter inventories for the time period of this study. The Army phased out over 300 older AH-1s during the period and introduced over 700 new AH-64s (16:10). This modernization has had a substantial effect on operating costs. Table 3 also shows the annual operating cost figures for attack helicopters and indicates that the AH-64s are nearly twice as expensive as the AH-1s (16:10).

Table 3. Attack Helicopter Modernization and Annual O&M Costs (FY96 $M)

Aircraft Type	FY75	FY95	Change
AH-1S	381.00	121.00	-260.00
AH-1G	31.00	3.00	-28.00
AH-1E		23	23.00
AH-1P	2.00	10.00	8.00
AH-1F	352.00	490.00	138.00
AH-64A		746	746.00

Aircraft Type	O&M ($M)
AH-1S	0.31
AH-64	0.57

The Army's experience in this mission area is typical of one in which substantial modernization has taken place during the 20-year period:

- O&M cost per flight hour is up,
- O&M cost per unit of asset value is down,
- O&M cost per unit of capability is down, and
- O&M cost per aircraft has been managed down somewhat by reducing flying hours (16:11).

The flying hour reduction per aircraft is small:

- In FY75, 133,046 flying hours were allocated among 766 aircraft to produce an average of 174 flying hours per aircraft per year (16:11).
- In FY95, 236,370 flying hours were allocated among 1393 aircraft to produce an average of 170 flying hours per aircraft, a decrease of approximately 2 percent (16:11).

Altogether, changes in the number and mix of aircraft between FY75 and FY95 and the differences in their operating costs substantially account for the $322 million increase in O&M cost in Table 2 (16:11).

Observation Helicopters.

For Observation Helicopters, Table 4 and Figure 14 show that between FY75 and FY95:

- The total number of aircraft decreased 35 percent,
- There is a 30-percent decrease in total O&M, and
- Asset value decreased by 27 percent (16:11).

Table 4. Observation Helicopter Data (In Constant-Year FY96 Dollars)

Data Element		FY75	FY85	FY95
Aircraft		2,470	2,324	1,606
O&M ($M)		120	113	83
Hours		481,650	453,180	313,170
Asset Value ($M)		313	297	228
TASCFORM		Not Available		
Average Age		4	14	19.3
Flying Hours Per Aircraft		195	195	195
O&M Per Aircraft ($K)		49	49	51
O&M Per Flight Hour ($)		250	250	264
O&M Per $10K Asset Value ($)		3,842	3,816	3,629
Equipment Data	OH-58A	1,479	1,368	782
	OH-58C	594	582	443
	OH-58D	5	7	327
	OH-6A	392	367	54

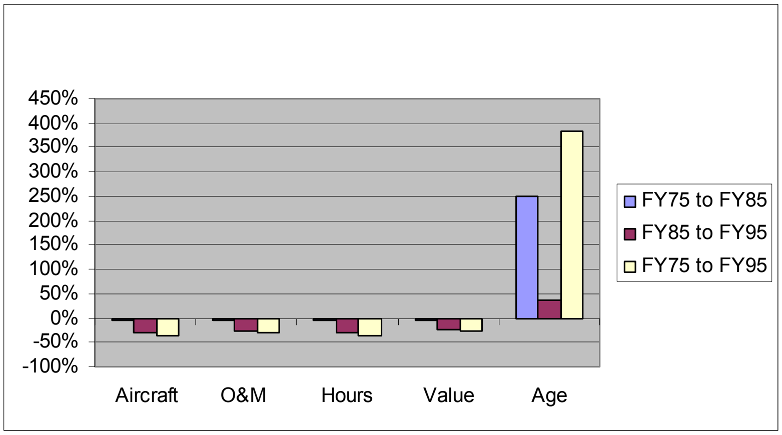

Figure 14. Observation Helicopters Total Resource and Performance Changes

The per unit section of Table 4 and Figure 15 show that between FY75 and FY95, the O&M cost:

- Per aircraft increased by 4 percent,
- Per flying hour increased by 6 percent, and
- Per $100K of Asset Value dropped by 6 percent (16:12)

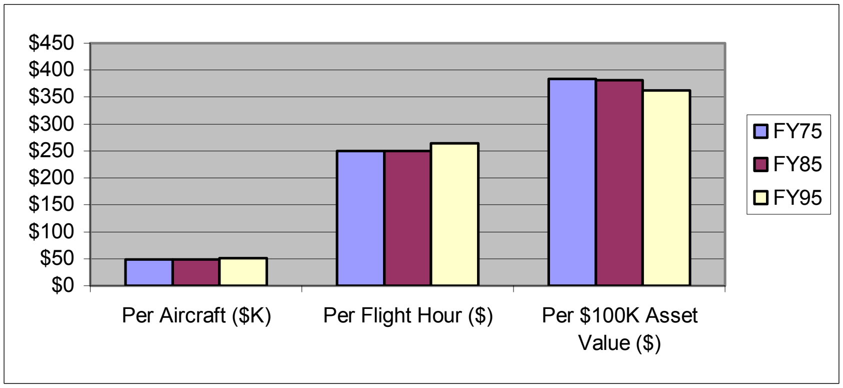

Figure 15. Observation Helicopter O&S Cost Ratio Changes

The Army bought new models of observation helicopters and reduced the size of its fleet during this period (16:13). Table 5 focuses on observation helicopter inventories for the time period of this study. The Army phased out 338 older OH-6A and 848 OH-58A-C models during the period and introduced 322 new OH-58Ds (16:13). This modernization has increased operating costs for observation helicopters. Table 5 also shows the annual operation cost figures for observation helicopters and indicates that the AH-64s are nearly twice as expensive as the OH-6s.

Table 5. Observation Helicopter Modernization and Annual O&M Costs (FY96 $M)

Aircraft Type	FY75	FY95	Change
OH-6A	392.00	54.00	-338.00
OH-58A	1479.00	782.00	-697.00
OH-58C	594	443	-151.00
OH-58D	5.00	327.00	322.00

Aircraft Type	O&M ($K)
OH-6	34.0
AH-64	67.0

The Army's experience in this mission area is one in which some modernization has taken place during the 20 year period (16:14). Also, a significant drawdown in the number of aircraft changed the model mix enough so that:

- O&M cost per flight hour is up, and
- O&M cost per unit of asset value is down (16:14).

The change in the number and mix of aircraft between FY75 and FY95 substantially accounts for the $37 million decrease in O&M costs shown for observation helicopters in Table 4 (16:14).

Utility Helicopters.

For Utility Helicopters, Table 6 and Figure 16 reveal several important changes between FY75 and FY95:

- The total number of aircraft decreased 25 percent,
- There is a 56 percent increase in total O&M, and
- Asset Value increased by 23 percent. (16:14).

Table 6. Utility Helicopter Data (In Constant-Year FY96 Dollars)

Data Element		FY75	FY85	FY95
Aircraft		4,430	4,427	3,335
O&M ($M)		331	476	517
Hours		952,450	951,131	715,783
Asset Value ($M)		3,598	7,716	9,558
Ton-miles per hour		945,362	1,191,810	1,167,006
Average Age		6.6	13.8	18.6
Flying Hours Per Aircraft		215	215	215
O&S Per Aircraft ($K)		75	108	155
O&S Per Flight Hour ($)		348	500	722
O&S Per $10K Asset Value ($)		920	617	540
O&S Per Capabiity Unit ($)		350	399	443
Equipment Data	UH-1B	430	55	38
	UH-1H	3,322	3,066	1,688
	UH-1M	309	246	
	UH-1V	369	386	367
	UH-60A		674	926
	UH-60L			316

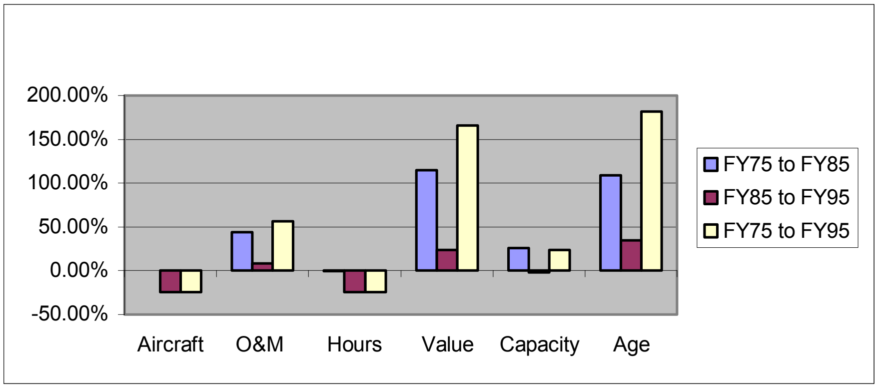

Figure 16. Utility Helicopters Total Resource and Performance Changes

Looking at the per unit section of Table 2-6 and Figure 2-16 we see that between FY75 and FY95 the O&M cost:

- Per aircraft increased by 107 percent,
- Per flying hour increased by 207 percent,
- Per $100k of Asset Value dropped by 166 percent, and
- Per unit of capability increased by 27 percent (16:14).

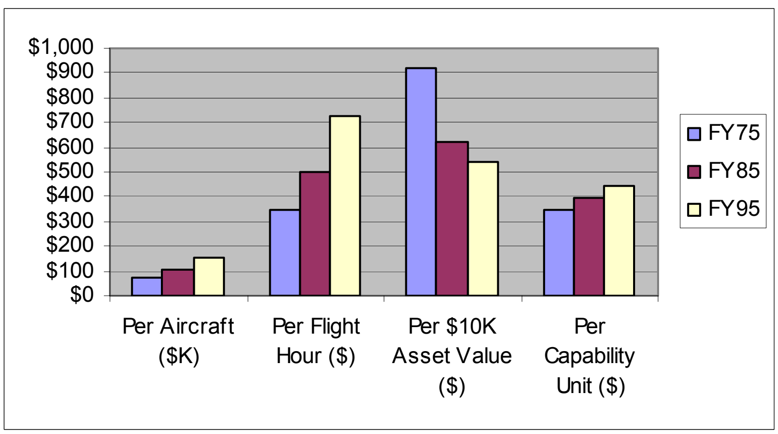

Figure 2-16. Utility Helicopter O&S Cost Ratio Changes

The Army modernized its utility helicopters during this period and reduced the size of its fleet (16:16). Table 7 focuses on Utility Helicopter inventories for the time period of this study. Lover 2,300 older UH-1 models were phased out during the period and over 1,200 new UH-60s were introduced (16:16). Table 7 also shows that this modernization has caused mission operating costs to increase, and also indicates that the UH-1s are much cheaper to operate than the UH-60s (16:16).

Table 7. Utility Helicopter Modernization and Annual O&M Costs (FY96 $M)

Aircraft Type	FY75	FY95	Change
UH-1B	430	38	-392
UH-1H	3,322	1,688	-1,634
UH-1M	309		-309
UH-1V	369	367	-2
UH-60A		926	926
UH-60L		316	316

Aircraft Type	O&M ($K)
UH-1H	54.0
UH-60A	194.0
UH-60L	305.0

The change in the mix of aircraft between FY75 and FY95 substantially accounts for the $186 million increase in O&M costs shown for Utility Helicopters in Table 6 (16:16). The Army's experience in this mission area is typical of one in which moderate modernization has taken place during the 20 year period:

- O&M cost per flight hour is up, and
- O&M cost per unit of Asset Value is down (16:17).

However, in the case of utility helicopters, O&M cost per unit of capability is up (16:17). The study shifts its attention to case studies comparing O&S costs and characteristics of similar weapon systems. Two studies that are of particular interest are Attack Helicopters: AH-1s vs. AH-64A and Utility Helicopters: UH-1H vs. UH-60A.

Attack Helicopters: AH-1s vs. AH-64A.

Comparative O&S cost and helicopter characteristics are summarized in Table 8 for the Cobra (AH-1) and the Apache (AH-64A) attack helicopters (16:19). Total O&S costs for the AH-64A are 71 percent higher than comparable costs for the AH-1S (16:20). Consumables and component reparables show much larger than average increases while ammunition, intermediate maintenance, and depot end-item maintenance were less (16:20).

Table 8. O&S Costs for Attack Helicopters (In Constant-Year FY96 $M)

Cost Element	**AH-1S**	**AH-64A**
Fuel	8,648	10,220
Ammunition	38,532	7,497
Consumables	11,262	60,494
Repairables (Net)	150,352	326,922
Intermediate Maintenance	28,253	22,782
Depot Maintenance (End Item)	14,756	1,769
Annual Direct O&S Cost	251,803	429,685
Flight Hours Per Year	130	130
Direct O&S Cost Per Flight Hour	1937	3305
Cost Ratio	1	1.71
Characteristics		
Max TOGW (lbs.)	10,000	14,694
Empty Weight (lbs.)	6,598	11,387
Max Speed (knots)	133	158
Operating radius (miles)	369	300
Endurance (hours)	2.6	1.83
Fuel Capacity (gallons)	262	370
Crew	2	2
Asset Value ($M)	3.7	12.81
Capability (TASCFORM score)	3.182	10.47
Weapon Control	AWG-10	AWG-9
Armament	20-mm cannon	30-mm chain gun
	8 TOW missiles	Hellfire missiles
	76 2.75-in. rockets	Hydra 70 rockets

The AH-64A is larger, heavier, and faster than the AH-1S and has a more sophisticated armament and fire-control system (16:20). The asset value of the AH-64A is 246 percent higher than for the AH-1, and the TASCFORM score, a measure of weapon system capability, is 229 percent higher for the AH-64A (16:20). The AH-64's asset value and capability grew faster than its O&S cost, which results in a lower O&S cost per unit of asset value or capability than for the AH-1S.

Utility Helicopters: UH-1H vs. UH-60A.

Comparative O&S cost and helicopter characteristics are summarized in Table 9 for the Huey (UH-1H) and Blackhawk (UH-60A) utility helicopters (16:20). The UH-60A is more than twice the empty weight of the UH-1H, and it has the capability to carry twice as much cargo (externally loaded) (16:20). The maximum speed is 145 knots compared to 107 for the UH-1H. The asset value of the UH-60A is 615 percent higher than for the UH-1H (16:20). The UH-60A is 172 percent higher in terms of ton-miles per hour, a measure of capability used for cargo carrying non-combat vehicles (16:20).

Table 9. O&S Costs for Utility Helicopters (In Constant-Year FY96 $M)

Cost Element	UH-1H	UH-60A
Fuel	9,104	10,220
Ammunition	259	7,497
Consumables	4,843	60,494
Repairables (Net)	43,782	326,922
Intermediate Maintenance	32,599	22,782
Depot Maintenance (End Item)	8,674	1,769
Annual Direct O&S Cost	99,261	429,685
Flight Hours Per Year	150	130
O&S Cost Per Flight Hour	662	3305
Cost Ratio	1	2.77
Characteristics		
Max TOGW (lbs.)	9,500	14,694
Empty Weight (lbs.)	5,210	11,387
Max Speed (knots)	106.7	158
Combat radius (miles)	317	300
Fuel Capacity (gallons)	209	370
Payload	4,000 lbs external	8,000 lbs external
	or 10 passengers	11 combat troops
Crew	3	3
Asset Value ($M)	0.923	6.6
Capability (Ton-miles per hour)	213.4	580
Armament	3 x 7.62-mm MGs	2 x 7.62-mm MGs

O&S costs for the UH-60A are 177 percent higher, asset value is 615 percent higher, and capability is 172 percent higher than for the UH-1H. The UH-60's capability grew at about the same rate as its O&S cost, which resulted in a similar O&S cost per unit of capability compared to the UH-1H (16:21). The UH-60's asset value grew faster than its O&S cost, which results in a lower O&S cost per unit of asset value (16:21).

The Department of the Navy and the Department of the Air Force sections of this study examines the Air to Ground Mission Categories for each service. However, neither of these sections or mission categories addresses O&S costs of Navy or Air Force helicopters. This further validates the need for research in these areas and lends credit to the methodology of this research.

Parametric Cost Modeling for Navy Aircraft.

Parametric models have been developed for numerous weapon systems to provide cost analysts with tools useful for predicting costs for analogous systems. Parametric estimating and time series forecasting are the primary methods for estimating future costs. This thesis focuses on the latter rather than the former. It is important to understand what parametric modeling accomplishes in the way of predictive analysis. In his thesis entitled, *A Parametric Cost Model for Estimating Operating and Support Costs of U.S. Navy Aircraft*, Mustafa Donmez develops multiple parametric models to determine yearly O&S costs for new naval aircraft acquisition programs. Physical parameters such as thrust and weight are used to establish any relationships between the dependent and independent variables. The VAMOSC system is used to extract all historical aircraft information. Cost information is analyzed from FY87 through FY98 and is reported in constant FY00 dollars.

Donmez focused on two main objectives throughout his research. The objectives were to find the best fitting O&S model and to create a robust aircraft O&S cost estimating methodology for Navy cost analysts when limited information is available (17:5). Three distinct parametric cost models were built in the analysis. Donmez uses multivariate linear regression, a tree-based model, and single variable regression to construct the models (17:10).

The cost data supplied by the NCCA is broken out by different classes of aircraft. The four categories are as follows: Fighter/Attack (FA), Cargo/Utility (C/U), Rotary-

Wings (HELO), and Other (OTH) (17:14). Multiple T/M/S aircraft were removed from the analysis due to small sample size. Natural Logarithms were use to transform the data for the purpose of normalization. After eliminating specific T/M/S from analysis and transforming the data, two assumptions were validated:

- The weighted average annual cost for any aircraft T/M/S is constant; it does not systematically increase or decrease annually (17:18).
- Annual O&S cost observations are random samples and drawn from a hypothetical population of aircraft (17:18).

In the multivariate model, the following independent variables were used to examine significant effects on O&S costs (17:34):

- **Commands**- Atlantic Fleet (LANFLT), Pacific Fleet (PACFLT), NET (Naval Education and Training), Naval Air Systems Command (NAVAIR), Naval Forces Europe (NAVEUR), Reserve Commands (RESERVE), and MISC (Miscellaneous)
- **Weight**- Continuous Variable (in lbs)
- **Length**- Continuous Variable (in ft)
- **Wing Span**- Continuous Variable (in ft)
- **Height**- Continuous Variable (in ft)
- **Thrust**- Continuous Variable (in st lb)
- **Type**- Categorical Variable (A/F, C/U, OTH, HELO)
- **Speed**- Continuous Variable (in mph)
- **Crew**- Categorical Variable (Number of Manpower on Board)

- **Engines**- Categorical Variable (Number of Engines)

The results of the multivariate model demonstrate that wingspan and height have an effect on O&S cost growth and weight, engine number, and thrust do not affect O&S costs when other independent variables are present (17:40). Stepwise regression was used to determine the utility of the model. The multivariate model exhibits the best summary statistics out of the three models but it is the least useful model. There are too many independent variables in the equation to have any practical use for accurate prediction.

The second model constructed, the tree-based model, provides the best model for estimating O&S costs. The results prove more reliable than the other regression-type models. Tree models successively split data into homogeneous subsets (17:46). Tree-based models can be described as "a recursive procedure resulting in terminal nodes or "leaves" containing groups of cases with similar values in their independent variables, which reflect response probabilities" (17:46).

The tree-based model for this particular research splits the data into two subsets: Reserve and Non-Reserve data. Each T/M/S was further broken into the four aircraft categories mentioned previously. Weight, length, and thrust were used as predictor variables because of their alleged relationship with O&S cost. The original model resulted in a tree with 51 nodes and a standard error of approximately 1.5 (17:48). The model was reduced to a 10-node tree with an increased standard error of approximately 0.1. The 10-node tree is more easily interpreted than the 51-node tree.

The last model analyzed used univariate regression as a predictor of O&S costs. Again, the same predictor parameters of weight, length, and thrust were used because of the perceived relationship with O&S costs. All of the predictive measures exhibit poor summary statistics when analyzed in a statistical software package. The parameter variables do show some predictive capabilities confirmed by the low F-statistic values (17:58-68).

The final conclusion of Donmez's research indicates more work needs to be focused in finding better predictive models for estimating O&S costs. The univariate and multivariate models show that "O&S costs of future aircraft acquisitions are not well-modeled by the physical and performance parameters identified in this study" (17:69). The performance parameters do affect O&S costs but they are not successful in explaining costs. The regression models analyzed provide rough-order-of-magnitude (ROM) estimates for analysts that do not possess the time nor experience to complete a comprehensive analysis for future O&S costs for a weapon system. The tree-based model provides the most successful model in terms of overall use coupled with predictive capability.

Parametric Cost Modeling for Air Force Aircraft.

While studying at the Naval Post Graduate School, Wu Ming-Cheng completed a thesis that explored O&S parametric modeling for all Air Force aircraft from FY90 through FY98. Ming-Cheng developed his research from a prior RAND study that built cost-estimating relationships (CERs) for Air Force aircraft from FY81 through FY86. Ming-Cheng reported that flyaway costs and flying hours were the major cost drivers during that period (18:2). Additionally, the Ming-Cheng thesis reported modest cost growth as the aircraft fleet aged.

Ming-Cheng attempted to determine if the cost drivers for O&S costs observed during the years of the RAND study still applied to Air Force aircraft in recent years. The ability to retrieve O&S aircraft cost data is easier now that the AFTOC system is fully operational. Ming-Cheng cited three subsystems broken down in the AFTOC database: Weapon System Support Cost (WSSC), Component Cost System (CSCS), and Source Data Preprocessor (SDP) (18:5-6). Ming-Cheng's thesis specifically focused on the WSSC subsystem of the AFTOC.

Ming-Cheng develops three models using regression analysis to obtain the best equation for successfully predicting O&S costs for aircraft models. Flying hours, flyaway costs, number of aircraft, and aircraft fleet ages are the independent variables in the analysis (18:37-40). Additionally, Ming-Cheng adds dummy variables for type of aircraft. Aircraft types are broken down into three categories: fighter/attack, cargo/tanker, and other. The results of the regression analysis provides a similar conclusion to the previously mentioned RAND study that examined O&S cost drivers for Air Force aircraft. Average flying hours, number of aircraft, flyaway costs, and fleet age are all significant in predicting whether or not a certain type of aircraft will experience O&S cost growth. The flyaway cost variable is noted as possibly the most significant explanatory variable in predicting O&S cost growth (18:49).

O&S Cost Reduction – U.S. Navy.

O&S reduction initiatives are at the forefront for all service branches. Significant cost savings were identified for the Navy in its replacement timing of its H-3 helicopter fleet with the CH-60. The Sikorsky H-3 helicopter has been in service for an average of 34 years (19:2). The Navy has 54 in its inventory and has projected the first replacement

CH-60 to occur in the year 2008 (19:2-3). Even though the H-3 fleet recently underwent an overhaul process, maintaining these old aircraft will become increasingly expensive (19:2).

The H-3 performs the following missions for the Navy:

- Executive battle staff transportation- the movement of very important person (VIPs) from ship to ship, ship to shore, shore to ship, or shore to shore.
- Search and rescue
- Passenger/Mail/Cargo Services and Air
- Torpedo/Drone recovery
- Special warfare support

The CH-60 will be able to meet all the above mission requirements along with additional capability. The addition of external fuel tanks will allow an endurance increase up to six hours (19:10). Air speed with the CH-60 will be faster, between 150 and 175 knots compared to 120 knots of the H-3. It will also have a more modern computerized hovering system, allowing it more stability when hovering (19:11). The CH-60 will also be able to carry up to 5,500 pounds of palletized cargo, as well as a 9,000 pound cargo hook compared to a 6,000 pound hook for the H-3 (19:13-15). Finally, the CH-60 will have self protection available, making it equipped to perform many of its duties in more hostile environments if necessary (19:16). "It will have ballistically tolerant fuel systems, flight controls and dynamic components. It will have infrared suppression, wire strike protection, and chaff and flare dispensers" (19:15-16).

In order to compare the benefits of replacing the H-3 with the CH-60, a comparison of historical costs is performed. From FY86-FY96, the Navy operated seven models of the H-3 helicopter (19:21). One of the models, the SH-3H, was used for anti-submarine warfare and not combat support mission, so data for this version was not included in the calculation of O&S costs for the H-3 (19:21). The data for the total yearly O&S cost for the six models is derived from the Navy's VAMOSC system. The total annual O&S cost for the H-3 was found by adding the costs for each of the ten years. The total O&S costs are approximately $1.1 billion (FY97 constant dollars) (19:21-22). The total flying hours for each model by year is also available in the VAMOSC database, which sums across the ten year period to 200,580 hours (19:27). The average O&S cost per flight hour is found by dividing the total annual cost by the total flying hours, which was $5,324 (1997 constant dollars) (19:28).

Now that an average cost per flight hour is determined for the H-3, similar calculations are performed for the CH-60. At the time of the comparison, the CH-60 had not entered into Navy service, so historical O&S cost data was unavailable (19:29). The Navy VAMOSC system has data available on the HH-60 helicopter, which is the closest aircraft in mission and configuration to the CH-60 (19:29). The HH-60H Sea Hawk is regarded as the best surrogate for CH-60 O&S costs (19:31). Data was available for the Sea Hawk from FY90-FY96 (19:32). The estimated CPFH for the HH-60H is $3,347 (19:38).

The estimated savings in O&S costs per year are found by multiplying an average utilization rate of 342 hours per helicopter by the number of H-3s in the Navy's inventory by each of the determined CPFH figures previously calculated (19:40-41). The total savings achieved by replacing the H-3 now, as opposed to later, is $36.5 million annually (19:45).

The current plan involves replacing the H-3 starting in FY08 by procuring six the first year, followed by 18 each year until 42 CH-60s were available to replace 54 H-3s (19:42). The proposed plan involves accelerating the procurement by eight years and increasing the first purchases up to 36 aircraft (19:44). The total O&S savings for the period from FY00-FY10 are approximately $292 million (19:45).

Since the planned replacement of the H-3 with the CH-60 was not a one-to-one replacement, base operating and support costs would also be much lower (19:46). These costs are incurred by the facility that supports the squadron that operates the aircraft and include such things as lodging, personnel support, and general support (19:46). Finally, "increasing the number of helicopters purchased per year would allow the manufacturer to take advantage of economies of scale and spread the fixed costs of the production of the aircraft over more units" (19:47). The procurement cost per unit would be lower, compensating the cost of replacing the helicopters sooner (19:47).

Assessing Competitive Strategies for the Joint Strike Fighter.

The management team of the Joint Strike Fighter (JSF) saw the importance of reduced O&S costs in the early concept and development stages of the program. The management team wanted to analyze the benefits to be realized in O&S cost savings by introducing contractor competition during the Engineering and Manufacturing Development (EMD) and production phases. The idea is that such competition will lead to better design and production, which also leads to better reliability during field operations. A frequently referenced example is the great engine war, which pitted General Electric's F-110 engine against Pratt & Whitney's F-100 engine to induce Pratt & Whitney to produce a more reliable version of the F-100 engine (20:65). DoD relied on the fact that higher reliability will lead to a reduction in O&S costs. The JSF management team decided to examine the extent of possible competition-induced reductions in O&S costs to see if such reductions might be large enough to affect their estimate of the likelihood of breaking even by introducing a second-source producer (20:65). The analysis of this O&S costs reduction effort followed a four-step approach:

1. Elements of O&S costs were identified that were likely to be affected by the contractor’s actions during EMD and production in a typical military aircraft program. This was done by reviewing the categories by which O&S costs are typically reported and judging which of those would be likely to change as a result of changes in system reliability.

2. The magnitudes of those competition-sensitive O&S costs in the JSF were determined, as currently estimated its projected operational life. The JSF Program Office provided this data.

3. The sensitivity of those competition-sensitive O&S costs to changes in reliability was calculated. Those estimates, made by the Naval Air Systems Command (NAVAIR) using the JSF O&S cost estimation model, yielded a range of possible savings resulting from competition during production, expressed as a percentage change in certain JSF O&S costs.

4. The Savings were used to adjust previously reported break-even calculations to determine whether the projected O&S cost savings led to a significant change in the overall likelihood of breaking even (20:65-66).

In step one, management concluded that contractors have the highest level of potential influence over O&S costs in five areas: unit-level consumable supplies, DLRs, airframe overhauls, engine overhauls, and support equipment repair (20:66). In step two, engine overhauls were excluded because competition for engine EMD and production is already planned. Percentages of O&S costs were determined for consumables, DLRs, and overhauls. It was determined in steps three and four that competition-induced improvements in system reliability are likely to yield O&S dollar savings over the operational life of the JSF fleet. However, the reductions realized would not be large enough to overcome the cost penalties of introducing competition (20:72).

Air Force Flying Hour Program- Historical Problems.

The Air Force has experienced problems with accurately forecasting flying hour program estimates, mainly due to the confusion over how to define flying hour consumable supplies. "Up until FY92, when wing financial analysts used the term 'flying hour program', they were referring to consumable supplies used to maintain their wing's aircraft" (21:1). The term 'flying hour program' is redefined and includes many more elements when funding for DLRs and Aviation Petroleum, Oil, and Lubricants (AVPOL). These components were de-centralized to the wing level (21:1).

For years, the financial community had worked diligently on the task of clearly defining and properly measuring the flying hour consumable supplies program (21:1). With the de-centralization of DLRs and AVPOL, work was left unfinished and a more clear-cut definition was needed (21:1).

Since 1980, financial analysts had significant problems with the planning, programming, and budgeting for flying hour consumable supplies (21:2). Since there was no Air Force-wide definition of consumables, each MAJCOM distributed funding, tracked expenditures, and performed analysis based on its own definition (21:2). Another issue that arose involved the different philosophies among the MAJCOMs (21:2). "While one command might consider flying hour related costs to include any costs directly or indirectly related to maintaining the aircraft, another might use a stricter definition and only include costs directly related to maintaining the aircraft" (21:2).

While funding decentralization and supporting the growth of the flying hour program, wing and MAJCOM levels had a more critical task of justifying funding requirements and also spending reduction with funding already in place (21:2-3). The inconsistent consumable supply definitions identifying the criteria used to calculate flying hour expenses used by the MAJCOMs, as well as the wings, made all taskings extremely difficult (21:3). At the time, consumable supplies shared the same accounting codes with non-flying mission items. A financial analyst had to manually separate the flying mission items from non-flying items, a very time-consuming task prone to error (21:8). If consumables had their own unique accounting code, retrieving the needed information specifically for flying-mission items would be much simpler and allow the analyst to construct a true picture of flying hour expenditures (21:8). Due to cost reduction efforts DoD-wide, more accurate information is critical for leaders to make informed decisions (21:8).

A formal definition of what qualifies as flying hour consumables must be developed and distributed (21:9). "This definition should not be based on where an item is purchased, but what an item is and how it relates to the flying mission" (21:9). The definition should include a formalized list of criteria, with examples to aid personnel in determining whether an item should be classified as flying hour-related (21:9).

Cost Per Flying Hour Calculation.

In a thesis entitled *Flight Hour Costing at the Type Commander and Navy Staff Levels: An Analytical Assessment*, Michael Edwards examines the Navy Flying Hour Program (FHP) and assesses the models used at the operational level, the community sponsor level, and the budgeting level (22:6). The Navy FHP "is the primary vehicle through which the Service maintains a readily available force of combat and support aircraft, aircrews, and ground support personnel" (22:7). Edwards concentrates his research on the Pacific Fleet (COMNAVAIRPAC). One goal of the thesis was to "provide guidelines for budget control to more accurately predict variances as well as the average flight hour costs by aircraft type" (22:3-4). Edwards claims that FHP estimates are not correct during budget formulation because FHP funds are capped by Congress (22:2). The computation for FHP funding is calculated by multiplying required flight hours to sustain a planned proficiency by the CPFH of each specific T/M/S of aircraft (22:1-2). The research explores alternate methods of predicting FHP costs in searching for a better way of estimating future costs.

Edwards asserts that inaccurate estimates for the FHP adversely affect mission readiness. The research provides Type Commanders and Naval Air Station comptrollers with the current factors that affect FHP calculations so that true FHP predictions reflect all of the crucial factors involved in forecasting FHP projections. Edwards describes the procedures involved in the budget submission process for the FHP. The calculation for the annual budgeted cost for active duty units is as follows:

- (Primary Authorized Aircraft per sqdn) x (Crew Seat Ratio) = Allowed Crews per Squadron (22:17).
- (Allowed Crews) x (Aircrew Manning Factors) = Budgeted Crews per Squadron (22:18).
- (Budgeted Crews) x (Req. Hrs/Crew/Month) x (12 mos.) = Annual Flying Hours Required per Sqdn (22:18).

- (Ann. Flying Hrs Req. per Sqdn) x (Number of Sqdns) = Total Annual Flying Hours Required (22:18).
- (Total Ann. Flying Hrs Req.) x (Primary Mission Readiness percentage) = Annual Budgeted Flying Hours (22:18).
- (Ann. Budgeted Flying Hours) x (CPFH) = Annual Budgeted Cost, Active Duty forces (converted to "then-year" dollars) (22:18).

Each individual unit submits requirements through the chain of command during the budget cycle. The units are compiled and later combined with the other services inputs. Reviews are conducted until OSD and the Office of Management and Budget (OMB) agree on the funding items. Eventually, the submission for the FHP becomes part of the Federal Budget submission to Congress.

Edwards describes the relationship between the players involved in submitting the flight hour costing information as well as the CPFH determination. The office of the Special Assistant for the Flying Hour Program (N889E) collects flight information compiled into a database dating back to 1982. The Type Commanders submit data in Flight Hour Cost Reports (FHCR) that separate the information into actual obligations taken from each T/M/S by total number and cost pool (22:42). The database is updated monthly. To make budgeted CPFH projections, the Navy Comptroller's Office calculates a three-year running average of the actuals presented by the Type Commanders on their FHCR's (22:42). After a three-year average is determined, the appropriate escalator factors for inflation are applied and a projection is forecasted. Any unforeseen event which may cause an extraordinary increase or decrease in actual funding is normalized to smooth the data for future forecasting.

One of the problems with CPFH determination deals with the consistency with matters of "conflicting data, computations, and priorities which should be addressed" (22:43). Organizations use different databases, formulas, and priorities when calculating CPFH numbers. Type Commanders must get their figures in line with the community sponsor or persuade the FHP office to change the way computations are made (22:45). Variances often arise between what is planned and what actually occurs. A negative CPFH variance is often viewed as damaging to the organization. At the unit level, the Type Commanders have developed factors influencing CPFH calculations. Some of the major factors include:

- **Unit Location-** "The operating environment of a squadron can have a significant effect on flying expenses" (22:46).
- **Operational Tempo (OPTEMPO) -** Funding is approved on a yearly basis. The operational tempo may vary extremely from year to year depending on the flow of operations (22:47).
- **Type of Flying-** "Whereas the Training and Readiness Matrices provide guidance as to the *number* of flight hours each event requires, it does not specify the intensity of the evolution" (22:48).
- **Non-PMA and Support Flights-** A portion of the missions flown do not count towards aircrew readiness. These miscellaneous flight hours must be flown by the units (22:48).
- **Aircraft Maintenance Costs and Human Error-** The cost of aircraft maintenance and repair is a core constituent in the CPFH equation. The collection

and reporting of maintenance requests and data submissions is a tedious process. Human error is likely to occur at some point in the process (22:49-50).

Army Flying Hour Program Methodology – Historical Problems.

The Army's flying hour program has been criticized in the past due to poor performance. During FY84-FY88, the Army under-flew its flying hour program by 35.6 percent, compared to an over-flight by the Navy of 2.3 percent and under-flight by the Air Force of 3.7 percent (23:3). Even though the Army has an aircraft fleet larger than the Navy, and as large as the Air Force, it did not have the necessary personnel in place to effectively manage its flying hour program (23:3). The Navy and Air Force had at least six individuals committed to the program, while the Army dedicated only one (23:4).

The Army improved its execution rate in its flying hour program from 87.4 percent in FY86 to 98.2 percent in FY88 (23:4). Despite this positive trend, then Executive Secretary to the Defense Resources Board (Programming Phase) David S. C. Chu directed the Army to submit a report to the Deputy Secretary of Defense no later than 1 May 1989, outlining plans for improving the management and oversight of the Aviation Flying Hour Program (23:4). Serious doubt still lingered in the DoD in whether the Army's procedures were strong enough to effectively plan and execute the flying hour program (23:4).

The under-execution of the flying hour program can be traced to the different methodologies used to predict flying hour requirements for the different commands. The methods used by unit, major command (MACOM), and Department of the Army levels were all different, leading to inaccurate and inflated requirements. The inflated requirements were difficult, sometimes impossible, for the Army units to attain. These inabilities lead to the program being under-flown.

At the unit level, the methodology was people and event-based (23:16). A unit commander considered the number of aircrew personnel and aircraft assigned, mission support requirements, hours necessary for maintenance, and the status of aviation and supported unit training (23:12). Training requirements were broken out to include: qualification training, refresher training, mission training and initial as well as refresher night vision goggle training (23:13). The hours required for each type of training were multiplied by the number of personnel to come up with a total hourly requirement. Simulator time was deducted from this total to come up with a net total hourly requirement for training (23:13). The second part of a unit's flying hour program entailed unique mission support and operational requirements, including: combat and combat support; executive and staff transport; aerial photography and mapping; research, development, test, and evaluation; aeromedical evacuation; and special missions unique to location and operation (23:13-14). The commander also estimated the level of training that could be accomplished collectively, as well as the hours required for maintenance activities (23:14-15). A model detailing the flying hour requirements for each helicopter in a unit was completed and forwarded to the MACOM responsible for funding allocation of the flying hour program. It should be pointed out again that the unit level methodology was people and event-based in order to properly compare it to the methodology of the Department of the Army, which is explained later.

The MACOM aviation officer relies on military judgment, expertise, and historical data to identify any deviations from what would be considered normal for a particular unit (23:19). The MACOM simply totaled requirements for all subordinate units and forwarded the data for all aircraft systems to the Department of the Army Headquarters for funding (23:19-20). The Department of the Army based predictions for the flying hour requirements on the assumption that for every airframe there is one and only one crew available to fly the aircraft (23:23). The Department of the Army level was airframe based while the subordinate units, or actual users of the flying hours, was based on crews available and annual personnel turnover rates (23:23). Typically, aviation units are undermanned, leading to an overstatement of requirements with the airframe based methodology (23:23).

As much as possible, Army Headquarters rolled up all the MACOM requests for flying hour funding into the Army's POM. Since concerns about the accuracy of the requests abounded, the Army staff responsible for the flying hour program re-computed the data using an Air OPTEMPO rate (23:25). This rate was an indicator that expressed flying hour requirements, resourcing levels, and execution in terms of flight per-crew per-month for rotary wing aircraft (23:25). This rate was applied to the active component's six combat commands (23:25). For example, the Air OPTEMPO rate for FY89 was 15.0 hours (23:25). For a unit with 21 aircraft assigned, the number of hours required for the year would be found by multiplying 15 hours by 21 aircraft by 12 months to arrive an annual requirement (23:25). Since the airframe based methodology assumes one aircrew per airframe, this lead to a requirement overstatement (23:26). After applying this procedure across the entire service, Army Headquarters was seeking more hours than the individual units could fly (23:26). This situation gave the impression that the Army was either very inefficient in executing its flying hour program or very inaccurate at predicting requirements (23:26).

Chapter Summary

In this chapter, we document the implications of O&S costs on the total life-cycle cost of weapon systems and discuss how these costs continually increase. The O&S regulations provided by the DoD are explained in detail. The instructions show what data the services are required to track in order to reduce O&S costs associated with major acquisition programs, as well as systems currently in inventory. Along with the establishment of the VAMOSC system for each service, these efforts were intended to allow more accurate estimates of O&S costs and better budgeting. From the perspective of the Air Force and Navy, the efforts to develop predictive models for O&S costs have had mixed results. Due to the size and complexity of O&S costs, it was determined that forecasting a small segment of these costs, the CPFH program, would be a better approach. Some of the historical problems with the CPFH calculations for all services were detailed in this chapter to show differences that lead to inaccurate estimates. Using the knowledge from these studies, this thesis O&S cost data will be analyzed to develop a simple forecasting model that can be easily used and understood.

III. Methodology

Chapter Overview

This chapter provides an in-depth view of the methodology that will be applied in conducting the research of estimating operating and support (O&S) cost per flying hour (CPFH) for Navy rotary wing aircraft. This chapter begins with a brief description of the VAMOSC database and explains how data was collected for this study. Next, the chapter focuses on the details of the empirical breakout of the Office of the Secretary of Defense/Cost Analysis Improvement Group (OSD/CAIG) format for O&S data for each helicopter by type/model/series (T/M/S). The following step analyzes the actual expenditures for CPFH for each helicopter studied; exploring different forecasting options to determine which option best fits each series of data. Any trends existing within the data set are discussed. Summary statistics are calculated to determine the best forecasting method for that particular helicopter. The final step in this methodology is to apply the chosen forecasting method in developing a forecast for fiscal year (FY) 2004 for each helicopter.

Database

As mentioned in Chapter I, the Visibility and Management of Operating and Support Costs (VAMOSC) database is used to gather the necessary data for the analysis and forecasting for this research. The database includes all major Navy weapon systems. VAMOSC was developed to satisfy Congressional O&S reporting requirements. The database contains all unclassified operating costs associated with a weapons system. The information maintained in the VAMOSC database is a collection of data from various sources. Flying hour data and aircraft inventory data is extracted from the Aviation Type/Model/Series Report (ATMSR).

The necessary data for the analysis and forecasting is accessed through the VAMOSC Aircraft T/M/S menu. Upon selecting the OSD/CAIG structure alternative by then-year or constant-year from the list of options, the User is taken to a search page that allows one to tailor the information depending on specific needs. From here, drop down menus allow for the selection of the type of helicopter. The OSD/CAIG data is then downloaded in the format as shown in Table 10, which contains the O&S Costs for the UH-3H.

Table 10. UH-3H ATMSR Data

CY FY04$	Maj. Clmnt	ElementLevel 1	ElementLevel 2	FY
13306	NET	7.0 Indirect Support	7.1 Personnel	2001
24963	NET	7.0 Indirect Support	7.1 Personnel	2002
316628	NET	1.0 Mission Personnel	1.1 Operations	1997
428332	NET	1.0 Mission Personnel	1.1 Operations	1998
1248441	LANFLT	1.0 Mission Personnel	1.1 Operations	2002
9964817	LANFLT	1.0 Mission Personnel	1.2 Maintenance	1997
10689811	LANFLT	1.0 Mission Personnel	1.2 Maintenance	1998

The User can sort the data by cost element structure (CES) component, Major Claimant, or FY. The Navy Major Claimants reported in the ATMSR are Commander in Chief U.S. Atlantic Fleet (CINCANTFLT), Commander in Chief U.S. Pacific Fleet (CINCPACFLT), Chief of Naval Reserve (CHNAVRES), and Chief of Naval Education and Training (CNET). The Commander in Chief U.S. Naval Forces Europe (CINCUSNAVEUR) is not separated at the individual Major Claimant level. CINCUSNAVEUR is instead combined with the CINCANTFLT data. The information for the Commander Naval Air System Command (NAVAIR) is not reported in the

ATMSR due to the Research and Development (R&D) type environment in which the command operates.

The VAMOSC data was sorted by CES, Major Claimant, and FY in a separate spreadsheet. Next, the costs were tallied for each CES and Major Claimant level. The VAMOSC breaks out the costs per the OSD/CAIG O&S Cost Estimating Guide from FY92. The new spreadsheet splits the costs as shown in Table 11. Table 11 displays the data for the UH-3H in FY97. The dollar amounts are given in constant year FY04 dollars. The spreadsheet shows the costs incurred by each Major Claimant, the flying hours flown by each Major Claimant, the O&S CPFH by Major Claimant, and the aggregate O&S CPFH for all Major Claimants combined.

Table 11. 1997 UH-3H Spreadsheet Data

CES	CINCLANTFLT	CINCPACFLT	CHNAVRES	CNET
1.0 Mission Personnel	$ 22,761,729	$ 9,956,576	$ 7,789,801	$ 2,286,246
2.0 Unit-Level Consumption	$ 17,907,768	$ 5,420,380	$ 4,002,614	$ 1,233,385
3.0 Intermediate Maintenance	$ 2,721,053	$ 1,125,742		$ 80,724
4.0 Depot Maintenance	$ 3,585,013	$ 497,493	$ 209,215	$ 86,637
5.0 Contractor Support	$ 91,483	$ 22,602		$ 11,839
6.0 Sustaining Support	$ 4,375,471	$ 1,094,184		$ 546,987
7.0 Indirect Support				
Total Cost	$ 51,442,517	$ 18,116,977	$ 12,001,630	$ 4,245,818
# of Aircraft	25	11	10	3
# Flying Hours	7,796	2,720	2,774	903
O&S CPFH	$ 6,598.58	$ 6,660.65	$ 4,326.47	$ 4,701.90

Total Overall UH-3H O&S Cost	$85,806,942
Total Overall UH-3H # of Flying Hours	14,193
Total Overall UH-3H O&S CPFH	$6,045.72

This data was extracted from VAMOSC for FY97-FY02 for each of the helicopters studied. Individual spreadsheets were developed for each helicopter in separate FYs in order to create a distinct time series for the forecasting process.

Empirical O&S Breakout

The ATMSR formatted data is used for the empirical O&S break-out. Each helicopter was evaluated from FY97-FY02 in total and by each Major Claimant. Line charts were created to show the percentage that each of the seven OSD/CAIG O&S cost element contributes to the entire cost for that FY, as shown in Figure 17 below. The percentage that each of the seven categories contributes to O&S costs provides a means to compare the costs from year to year without the outside influence of inflation. Increases due to inflation will apply to all of the categories. For each helicopter, the total percentage break-out for each FY will be compared to analyze any existing trends. Significant deviations in Major Claimant percentage break-outs will be addressed on an individual basis as required.

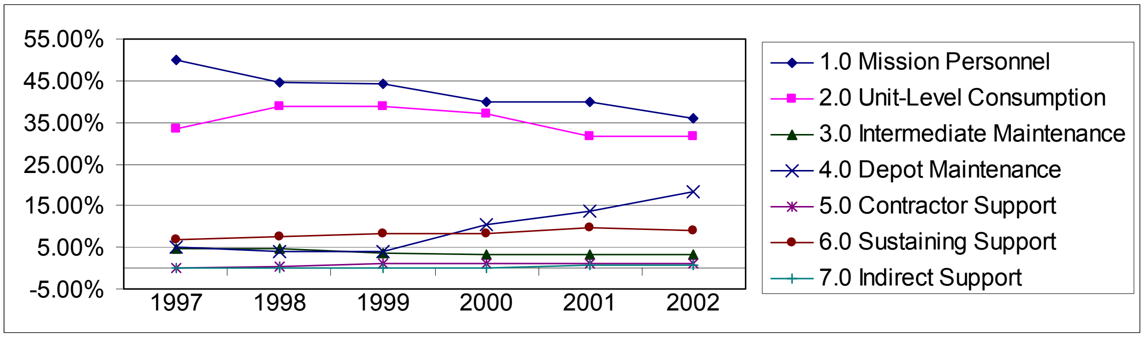

Figure 17. UH-3H Total O&S Cost Break-Out

Actual Cost Per Flying Hour Versus Budget Submissions

In this section, CPFH budget submissions for helicopters from FY97-FY02 are evaluated by comparing the figures to CPFH actuals downloaded from the VAMOSC database. A percent of error, or percent deviation, is calculated for each comparison to be made by using the following formula:

$$\frac{\text{actual} - \text{budgeted}}{\text{actual}} \cdot 100 \qquad (1)$$

Using the percent of error places emphasis on being over or under the budgeted CPFH. This is important because it shows if a constant trend exists of over-budgeting or under-budgeting. These errors are summarized and then re-addressed later when the forecasted CPFH is calculated and compared to the actual CPFH using the same formula.

Forecasting Options

For each helicopter being flown by a Major Claimant, three different forecasting techniques are used to evaluate the CPFH data extracted from the VAMOSC database. The forecasting techniques employed are the three-year moving average (MA3), the single exponential smoothing (SES) method, and Holt's linear method. The MA3 uses the average of the past three observations to forecast for the current period. The number of data points in each average remains constant and includes the most recent observations (24:142). The formula for an MA3 is:

$$F_{t+1} = \frac{1}{3} \cdot \sum_{i=t-2}^{t} Y_i \qquad (2)$$

Where F_{t+1} is the current forecast, Y_i is the i^{th} observation, and t is the sequence order number of the observation before the current forecast. This method was selected for use in this research mainly for its simplicity, as it is very easy to use and explain. The reason the order of the MA is three and not a higher order, such as five, is due to the fact that the data series is so small and having a larger order would greatly restrict the number of figures forecasted. The main problem with this forecasting technique is that it does not handle trends very well and can take several periods before the forecast can catch up to a level shift in the data (24:146).

The SES method uses the following formula to forecast for the next period:

$$F_{t+1} = F_t + \alpha\left(Y_t - F_t\right) \qquad (3)$$

Where, F_t is the most recent forecast, F_{t+1} is the current forecast, Y_t is the most recent observation, and α is a weight value between 0 and 1. The new forecast is essentially the previous forecast plus an adjustment for the error of the previous forecast. The level of alpha dictates how much the previous forecast error is weighted. The weight of the previous error increases as alpha increases and becomes closer to 1. The Solver function within Excel is used to find the optimal value for alpha for each SES forecast. Initialization of all of the SES forecasts is accomplished by using the first observed value as the first forecast, so that $F_1 = Y_1$. This forecasting technique was also selected for its simplicity of use and understanding. This method is good because as each new forecast uses the error of the previous forecast, it ends up using a weighting scheme that uses decreasing weights as the observations get older (24:147). The downfall of this forecasting method is the same as the MA3, in that it doesn't handle trends very well and it will trail any trend in the actual data (24:148).

Holt's linear method uses the following three formulas to forecast for the next period:

$$L_t = \alpha\ Y_t + (1 - \alpha)\ (L_{t-1} + b_{t-1}) \qquad (4)$$

$$b_t = \beta\,(L_t - L_{t-1}) + (1 - \beta)\,b_{t-1} \qquad (5)$$

$$F_{t+m} = L_t + b_t m \qquad (6)$$

Where L_t is an estimate of the level of the series at time t and b_t is an estimate of the slope of the series at time t, alpha and beta are smoothing constants between 0 and 1, Y_t is the most recent observation, L_{t-1} is the last smoothed value, b_{t-1} is trend of the previous period, and m is the number of periods ahead to be forecasted (24:158). This method of forecasting was selected because unlike the previous two methods, Holt's linear method can handle trends within the data (24:158). This method is also useful because it can forecast more than one period ahead, if needed. One of the cons of this method is that it can take the forecast a long time to overcome the influence of a shift in the opposite direction of the overall trend of the data (24:161). The main con of this method is the complexity involved in both using this method and explaining it to management lacking a background in forecasting.

Four evaluation measures are utilized for every forecast calculated. These measures include: The Mean Error (ME), the Mean Absolute Error (MAE), the Mean Percent Error (MPE), and the Mean Absolute Percent Error (MAPE). In considering all of these evaluation measures, it is more favorable to attain the least amount of error possible. The ME is simply the average of all of the error terms and uses the following formula:

$$ME = \frac{1}{n} \cdot \sum_{t=1}^{n} e_t \qquad (7)$$

Where e_t is the error (observation – forecast), and n is the number of observations. However, the ME is likely to be small since positive and negative errors tend to off-set one another (24:43). The MAE compensates for this bias by first taking the absolute value of each error term and then averaging the values. The formula for MAE is:

$$MAE = \frac{1}{n} \cdot \sum_{t=1}^{n} |e_t| \qquad (8)$$

The MPE is calculated by finding the percent of error for each term and then taking the average of those terms. The formula for MPE is:

$$MPE = \frac{1}{n} \cdot \sum_{t=1}^{n} PE_t \qquad (9)$$

Where PE_t is the percentage error [(actual-forecast)/actual]*100. As with the ME, the MPE allows terms to offset one another. The MAPE compensates for the bias of MPE by taking the absolute value of each percent of error and then taking the average. The formula for MAPE is:

$$MAPE = \frac{1}{n} \cdot \sum_{t=1}^{n} |PE_t| \qquad (10)$$

These four summary statistics measure the goodness of fit of the model to the historical data (24:45). All four statistics are evaluated as a whole because all of these measures together can tell a more complete story of goodness of fit than any individual summary statistic.

Actual Cost Per Flying Hour Versus the Forecast

After the forecast has been evaluated and the method of forecasting has been chosen for each time series being studied, the forecasted CPFH for FY00-FY02 is compared to the actual CPFH extracted from the VAMOSC database using the following percent of error formula:

$$\frac{\text{actual} - \text{forecasted}}{\text{actual}} \cdot 100 \tag{11}$$

These percent of errors will then be compared to the percent of errors computed when evaluating the accuracy of the budgeted CPFH.

Model Selection

With so many aircraft, one method might be best for predicting future costs for a certain helicopter and another method might be better in forecasting future costs for a different helicopter. A technique used to select the best forecasting overall method for each helicopter is needed. Theil's U is a useful statistic that allows a comparison between naïve methods and forecasting methods (24:48). Naïve forecasts are described as, "Forecasts obtained with a minimal amount of effort and data manipulation and based solely on the most recent information available are frequently referred to as naïve forecasts. One such naïve method would be to use the most recent observation available as the future forecast" (24:607). Additionally, large errors between observed and forecasted errors are given a lot more weight than smaller errors because the errors are squared (24:48). The formula for Theil's U is:

$$U = \sqrt{\frac{\sum_{t=1}^{n-1} \left[\left(FPE_{t+1} - APE_{t+1} \right)^2 \right]}{\sum_{t=1}^{n-1} \left(APE_{t+1} \right)^2}} \tag{12}$$

$$FPE_{t+1} = \frac{F_{t+1} - Y_t}{Y_t} \tag{13}$$

$$APE_{t+1} = \frac{Y_{t+1} - Y_t}{Y_t} \tag{14}$$

Where FPE_{t+1} is a forecast of the relative change and APE_{t+1} is a forecast of the actual relative change. F_{t+1} is the forecasted value following the current period. Y_t is the current observation. Y_{t+1} is the observed value for the next period.

Theil's U is a tool that provides an intuitive understanding in the selection process of finding the best forecasting method (24:48). The U-statistic with the lowest value serves as the best forecasting method. Theil's U is similar to using the MAPE of a forecasting method. The U-statistic is an accuracy measure used to integrate the naïve and forecasted models (24:49). When U equals 1.0, the naïve forecast is no better than the forecasting technique examined (24:50). When U is less than 1.0, the forecasting technique is better than the naïve forecast. The closer the U statistic is to 0, the better the forecasting method used (24:50). When U is greater than 1.0, there is no benefit to using the forecasting method, as the naïve method produces better results (24:50). The forecasting model providing the lowest U-statistic will be viewed as the best forecasting method. The method that significantly outperforms the other methods is chosen as the best overall method and is used to forecast FY04 data.

Forecasting for FY04

The final step of this research provides a forecast of the CPFH for FY04. This is accomplished upon the availability of the FY03 CPFH data within the VAMOSC database. The method chosen for each rotary aircraft in the Forecasting Options section is utilized to make the FY04 forecast. The FY03 data points are added to each applicable time series and the FY04 CPFH is calculated.

Chapter Summary

This chapter provides a roadmap for conducting the necessary research of this thesis. The methodology was presented in a logical order in which the research is conducted. The figures provide insight into the VAMOSC database and illustrate what to expect for the empirical O&S break-out section of Chapter IV. The formulas and their descriptions provide an in-depth look at the statistics used to evaluate not only the forecast, but also the budget submissions of each helicopter. Following the steps laid out in this chapter will provide answers to the research questions/objectives delineated in Chapter I.

IV. Results and Analysis

Chapter Overview

This chapter focuses on the results and findings from the models used to forecast cost per flying hour (CPFH) for the type/model/series (T/M/S) aircraft. For each helicopter, data depicting Office of the Secretary of Defense/Cost Analysis Improvement Group (OSD/CAIG) cost element structure (CES) trends is presented. Next, the forecasted values are displayed along with the best model for each helicopter. The actual CPFH numbers are compared to Program Objective Memorandum (POM) submissions and forecasted data. Finally, the best forecasting technique is selected and used to model CPFH figures for FY04. The OSD/CAIG can use the recommended model to forecast future CPFH data for comparison to the service's CPFH submissions.

CH-46D Helicopter Results

CH-46D CES Trends.

Tables 12 through 17 show FY97-FY02 costs associated with the CH-46D helicopter. Costs for all Major Claimants are broken out by CES based on the 1992 OSD/CAIG Operating and Support (O&S) Cost Estimating Guide. The Visibility and Management of Operating and Support Costs (VAMOSC) database gives the User the opportunity to export cost information broken down by Major Claimant, fiscal year (FY), and CES. The information is collected, sorted, and re-formatted in order to utilize the forecasting techniques to develop forecasting models. All costs reported in Tables 12 through 17 are reported in constant-year (CY) FY04 dollars. If any trends exist within the data, reporting the figures in a single CY captures the effects of inflation. The data shows O&S costs by Major Claimant, total O&S cost, number of flying hours flown, and overall O&S CPFH.

Table 12. 1997 CH-46D Costs

CES	CINCLANTFLT	CINCPACFLT
1.0 Mission Personnel	$ 16,072,388	$ 16,247,069
2.0 Unit-Level Consumption	$ 7,823,252	$ 9,919,329
3.0 Intermediate Maintenance	$ 2,659,421	$ 3,425,389
4.0 Depot Maintenance	$ 4,086,009	$ 3,971,720
5.0 Contractor Support	$ 59,195	$ 74,262
6.0 Sustaining Support	$ 6,471,722	$ 8,102,839
7.0 Indirect Support		
Total Cost	$ 37,171,987	$ 41,740,608
# of Aircraft	12	15
# Flying Hours	5,147	5,805
O&S CPFH	$ 7,222.07	$ 7,190.46
Total Overall CH-46D O&S Cost		
$78,912,595		
Total Overall CH-46D # of Flying Hours		
10,952		
Total Overall CH-46D O&S CPFH		
$7,205.31		

Table 13. 1998 CH-46D Costs

CES	CINCLANTFLT	CINCPACFLT
1.0 Mission Personnel	$ 14,612,272	$ 14,564,637
2.0 Unit-Level Consumption	$ 9,392,351	$ 9,805,576
3.0 Intermediate Maintenance	$ 1,278,495	$ 2,224,836
4.0 Depot Maintenance	$ 3,633,166	$ 5,768,679
5.0 Contractor Support	$ 56,525	$ 56,525
6.0 Sustaining Support	$ 4,010,184	$ 5,013,030
7.0 Indirect Support		
Total Cost	$ 32,982,993	$ 37,433,283
# of Aircraft	12	15
# Flying Hours	4698	3751
O&S CPFH	$ 7,020.65	$ 9,979.55
Total Overall CH-46D O&S Cost		
$70,416,276		
Total Overall CH-46D # of Flying Hours		
8,449		
Total Overall CH-46D O&S CPFH		
$8,334.27		

Table 14. 1999 CH-46D Costs

CES	CINCLANTFLT	CINCPACFLT
1.0 Mission Personnel	$ 12,620,185	$ 12,251,550
2.0 Unit-Level Consumption	$ 7,769,918	$ 16,736,285
3.0 Intermediate Maintenance	$ 1,469,588	$ 2,203,802
4.0 Depot Maintenance	$ 3,333,489	$ 4,050,432
5.0 Contractor Support	$ 49,655	$ 68,672
6.0 Sustaining Support	$ 2,441,240	$ 3,286,443
7.0 Indirect Support		
Total Cost	$ 27,684,075	$ 38,597,184
# of Aircraft	11	14
# Flying Hours	4861	5421
O&S CPFH	$ 5,695.14	$ 7,119.94
Total Overall CH-46D O&S Cost		
$66,281,259		
Total Overall CH-46D # of Flying Hours		
10,282		
Total Overall CH-46D O&S CPFH		
$6,446.34		

Table 15. 2000 CH-46D Costs

CES	CINCLANTFLT	CINCPACFLT
1.0 Mission Personnel	$ 13,232,131	$ 14,571,264
2.0 Unit-Level Consumption	$ 6,466,273	$ 13,243,335
3.0 Intermediate Maintenance	$ 1,361,446	$ 2,413,270
4.0 Depot Maintenance	$ 3,271,457	$ 3,996,327
5.0 Contractor Support	$ 59,636	$ 61,463
6.0 Sustaining Support	$ 1,889,086	$ 3,105,439
7.0 Indirect Support		
Total Cost	$ 26,280,029	$ 37,391,098
# of Aircraft	11	15
# Flying Hours	4675	6074
O&S CPFH	$ 5,621.40	$ 6,155.93
Total Overall CH-46D O&S Cost		
$63,671,127		
Total Overall CH-46D # of Flying Hours		
10,749		
Total Overall CH-46D O&S CPFH		
$5,923.45		

Table 16. 2001 CH-46D Costs

CES	CINCLANTFLT	CINCPACFLT
1.0 Mission Personnel	$ 14,078,358	$ 13,892,688
2.0 Unit-Level Consumption	$ 12,208,968	$ 14,075,080
3.0 Intermediate Maintenance	$ 1,553,755	$ 2,551,253
4.0 Depot Maintenance	$ 1,050,125	$ 1,862,618
5.0 Contractor Support	$ 123,541	$ 75,553
6.0 Sustaining Support	$ 1,663,559	$ 2,736,131
7.0 Indirect Support	$ 122,540	$ 197,771
Total Cost	$ 30,800,846	$ 35,391,094
# of Aircraft	11	$ 14
# Flying Hours	4692	$ 6,020
O&S CPFH	$ 6,564.55	$ 5,878.92
Total Overall CH-46D O&S Cost		
$66,191,940		
Total Overall CH-46D # of Flying Hours		
10,712		
Total Overall CH-46D O&S CPFH		
$6,179.23		

Table 17. 2002 CH-46D Costs

CES	CINCLANTFLT	CINCPACFLT
1.0 Mission Personnel	$ 7,246,030	$ 4,401,174
2.0 Unit-Level Consumption	$ 10,474,440	$ 10,340,247
3.0 Intermediate Maintenance	$ 1,315,552	$ 1,889,540
4.0 Depot Maintenance	$ 1,250,440	$ 562,850
5.0 Contractor Support	$ 170,541	$ 34,479
6.0 Sustaining Support	$ 1,913,821	$ 2,335,873
7.0 Indirect Support	$ 82,116	$ 47,291
Total Cost	$ 22,452,940	$ 19,611,454
# of Aircraft	5	6
# Flying Hours	4450	4099
O&S CPFH	$ 5,045.60	$ 4,784.45
Total Overall CH-46D O&S Cost		
$42,064,394		
Total Overall CH-46D # of Flying Hours		
8,549		
Total Overall CH-46D O&S CPFH		
$4,920.39		

The components of the CH-46D CES are analyzed and computed as a percent of total O&S cost. The percentages are tallied by year and by Major Claimant. Table 18 shows the results of the O&S CES components as percentages of total O&S costs. The

Major Claimant results are not shown individually. Instead, Table 18 shows the results of the Major Claimants collectively.

Table 18. CH-46D CES Elements as a Percentage of Total O&S Cost

CES	1997	1998	1999	2000	2001	2002
1.0 Mission Personnel	40.96%	41.43%	37.52%	43.67%	42.26%	27.69%
2.0 Unit-Level Consumption	22.48%	27.26%	36.97%	30.96%	39.71%	49.48%
3.0 Intermediate Maintenance	7.71%	4.98%	5.54%	5.93%	6.20%	7.62%
4.0 Depot Maintenance	10.21%	13.35%	11.14%	11.41%	4.40%	4.31%
5.0 Contractor Support	0.17%	0.16%	0.18%	0.19%	0.30%	0.49%
6.0 Sustaining Support	18.47%	12.81%	8.64%	7.84%	6.65%	10.10%
7.0 Indirect Support	0.00%	0.00%	0.00%	0.00%	0.48%	0.31%

In addition to the table above, a Figure 18 was created to visually describe the CES elements over time. The line chart makes it easier to examine any existing trends. Figure 18 shows the cost data as a percentage of the total cost. The costs are sorted by the seven CES components delineated in Tables 12 through 17. The costs represent all Major Claimants. CES components 3.0 through 7.0 appear stable over time. Mission Personnel seems to decrease over time while Unit-Level Consumption increases significantly over time. Over the period studied, Unit-Level Consumption increases by 27 percent while Mission Personnel decreases by approximately 13 percent.

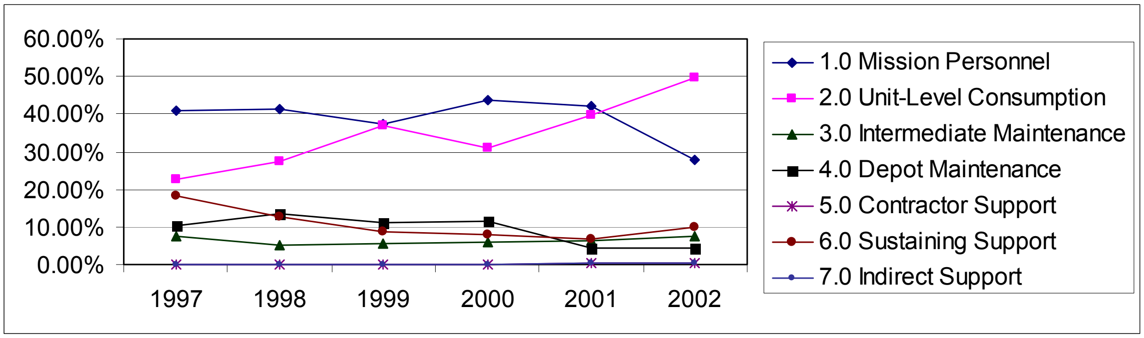

Figure 18. CH-46D CES Trends

Unit-Level Consumption, as reported in the Navy VAMOSC system, is comprised of fuel, Depot Level Reparables (DLRs), consumables, and other maintenance costs. This thesis concentrates on Unit-Level Consumption, since CES 2.0 contributes costs associated with CPFH. If the percentage of costs increases in the majority of the helicopter line charts, CPFH is increasing as a whole. The cost information for the other helicopters is presented later in this chapter.

CH-46D CPFH Trends.

An in-depth look at the CES 2.0 components is necessary to determine the primary cost drivers for CPFH. Tables 19 through 24 illustrate the CPFH break-out for the CH-46D helicopter. Additionally, Figures 19 through 24 show the CPFH percentage composition. Major increases or decreases to the CPFH components suggest cost drivers in developing trends.

Table 19. 1997 CH-46D CPFH

CES		CINCLANTFLT		CINCPACFLT
2.1 POL/Energy Consumables	$	593,912	$	621,925
2.2 Consumable Materials/Repair Parts	$	2,242,496	$	2,676,359
2.3 Depot Level Reparables	$	4,009,204	$	5,271,393
Total Cost	$	6,845,612	$	8,569,677
CPFH by Command	$	1,330	$	1,476
Total Overall CH-46D Flying Hour Costs				
$15,415,289.00				
Total Overall CH-46D CPFH				
$1,407.53				

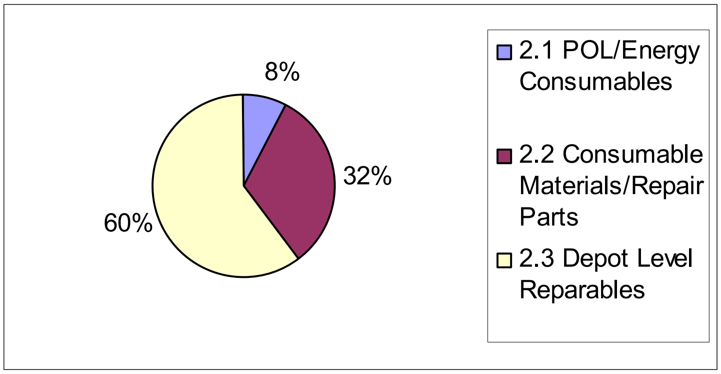

Figure 19. 1997 CH-46D CPFH Percentage Composition

Table 20. 1998 CH-46D CPFH

CES	CINCLANTFLT	CINCPACFLT
2.1 POL/Energy Consumables	$ 630,800	$ 490,145
2.2 Consumable Materials/Repair Parts	$ 1,996,227	$ 3,115,028
2.3 Depot Level Reparables	$ 5,801,138	$ 5,241,248
Total Cost	$ 8,428,165	$ 8,846,421
CPFH by Command	$ 1,794	$ 2,358
Total Overall CH-46D Flying Hour Costs		
$17,274,586.00		
Total Overall CH-46D CPFH		
$2,044.57		

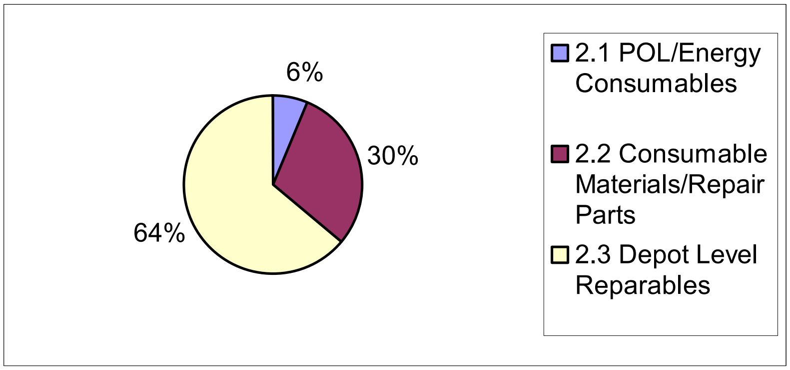

Figure 20. 1998 CH-46D CPFH Percentage Composition

Table 21. 1999 CH-46D CPFH

CES	CINCLANTFLT	CINCPACFLT
2.1 POL/Energy Consumables	$ 617,250	$ 625,276
2.2 Consumable Materials/Repair Parts	$ 2,563,108	$ 3,203,895
2.3 Depot Level Reparables	$ 3,918,355	$ 11,303,363
Total Cost	$ 7,098,713	$ 15,132,534
CPFH by Command	$ 1,460	$ 2,791
Total Overall CH-46D Flying Hour Costs		
$22,231,247.00		
Total Overall CH-46D CPFH		
$2,162.15		

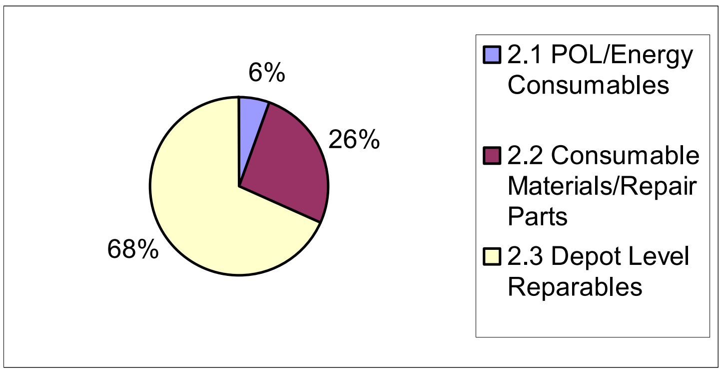

Figure 21. 1999 CH-46D CPFH Percentage Composition

Table 22. 2000 CH-46D CPFH

CES	CINCLANTFLT	CINCPACFLT
2.1 POL/Energy Consumables	$ 442,068	$ 541,427
2.2 Consumable Materials/Repair Parts	$ 2,889,457	$ 2,462,810
2.3 Depot Level Reparables	$ 2,533,242	$ 8,994,930
Total Cost	$ 5,864,767	$ 11,999,167
CPFH by Command	$ 1,254	$ 1,975
Total Overall CH-46D Flying Hour Costs		
$17,863,934.00		
Total Overall CH-46D CPFH		
$1,661.92		

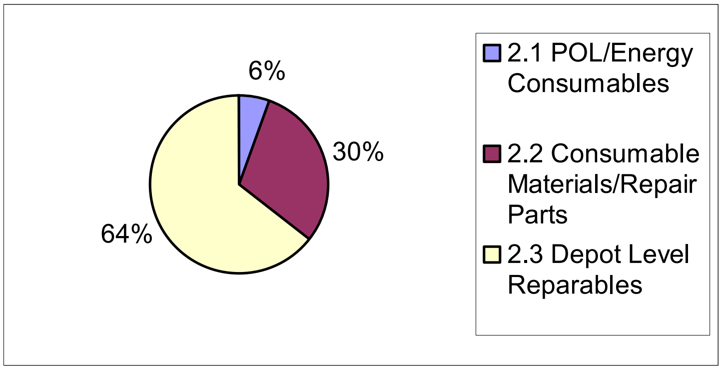

Figure 22. 2000 CH-46D CPFH Percentage Composition

Table 23. 2001 CH-46D CPFH

CES	CINCLANTFLT	CINCPACFLT
2.1 POL/Energy Consumables	$ 725,008	$ 874,434
2.2 Consumable Materials/Repair Parts	$ 5,863,993	$ 3,327,878
2.3 Depot Level Reparables	$ 5,180,156	$ 9,277,673
Total Cost	$ 11,769,157	$ 13,479,985
CPFH by Command	$ 2,508	$ 2,239
Total Overall CH-46D Flying Hour Costs		
$25,249,142.00		
Total Overall CH-46D CPFH		
$2,357.09		

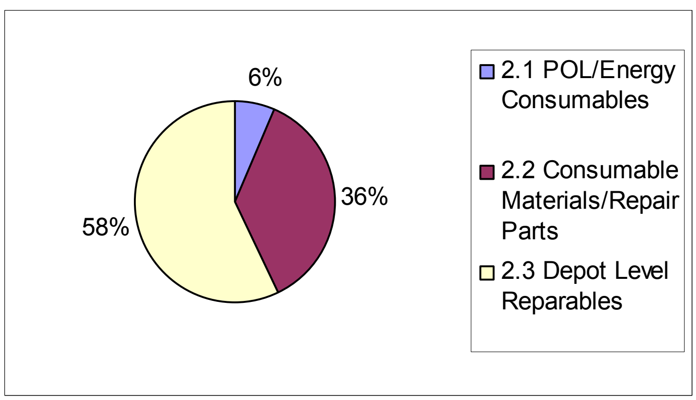

Figure 23. 2001 CH-46D CPFH Percentage Composition

Table 24. 2002 CH-46D CPFH

CES	CINCLANTFLT	CINCPACFLT
2.1 POL/Energy Consumables	$ 684,588	$ 587,390
2.2 Consumable Materials/Repair Parts	$ 3,392,769	$ 2,334,247
2.3 Depot Level Reparables	$ 6,183,310	$ 7,181,291
Total Cost	$ 10,260,667	$ 10,102,928
CPFH by Command	$ 2,306	$ 2,465
Total Overall CH-46D Flying Hour Costs		
$20,363,595.00		
Total Overall CH-46D CPFH		
$2,381.99		

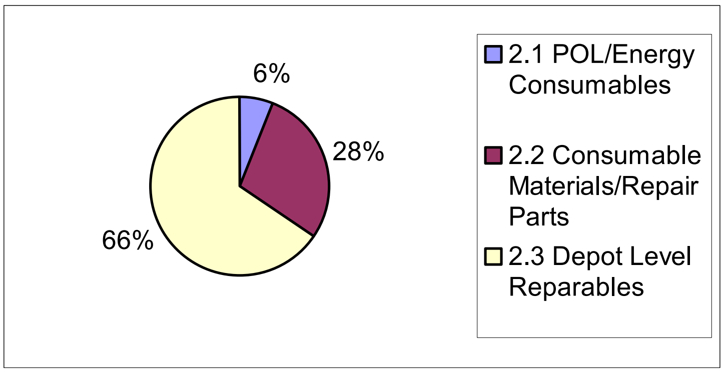

Figure 24. 2002 CH-46D CPFH Percentage Composition

It is important to note that CPFH dollars are in then-year (TY) format. The CPFH calculations differ from the CES percentage composition calculations in that the latter numbers are in base-year (BY) 2004 dollars. The reason behind converting all of the CPFH numbers into TY dollars has to do with forecasting. In forecasting, trends should be incorporated in the data set. If inflation is a factor, it needs to be addressed somewhere in the calculations. In using TY dollar amounts, inflation is already included in the data set. Therefore, the forecasted numbers developed will already account for inflation built in by the model.

The CPFH components for the CH-46D helicopter do not change much over the course of time. The main cost drivers are DLRs and consumables. Fuel is relatively stationary. CPFH costs generally trend upward with a noticeable dip in FY00. The dip is attributed to the decrease in DLRs for the CH-46D in both Major Claimants for that particular year.

CH-46D Forecasting Results.

Cost data in Tables 19 through 24 was used to develop models for predicting future costs. Three forecasting techniques, as described in Chapter III, were utilized to build the models. Table 25 shows the results from using the three-year moving average (MA3) method with historical CPFH data. Table 26 displays the results from the single exponential smoothing (SES) method. Table 27 calculates Holt's linear method. Separate models were built for modeling Major Claimants but only the total costs are presented in this thesis. The spreadsheet data for individual Major Claimant results are available for examination by the OSD/CAIG, but not included, due to the amount of data involved and the complexity of additional charts and information. For these reasons, only the total CPFH by helicopter is forecasted.

Table 25. CH-46D MA3 CPFH Calculation

	Yt	Ft	Error	|Error|	(Error/Yt)*100	|(Error/Yt)|*100
Fiscal Year	CPFH	MA3	Yt-Ft	|Yt-Ft|	Percent Error	Absolute Percent Error
1997	$1,408					
1998	$2,045					
1999	$2,162					
2000	$1,662	$1,871	-$210	$210	-12.61%	12.61%
2001	$2,357	$1,956	$401	$401	17.01%	17.01%
2002	$2,382	$2,060	$322	$322	13.50%	13.50%
2003		$2,134				
Total			$513	$932	17.90%	43.11%
			ME	MAE	MPE	MAPE
			$171	$311	5.97%	14.37%

Table 26. CH-46D SES CPFH Calculation

	α =	1		
Ft	**Error**	**|Error|**	**(Error/Yt)*100**	**|(Error/Yt)|*100**
SES	**Yt-Ft**	**|Yt-Ft|**	**Percent Error**	**Absolute Percent Error**
$1,408	$637	$637	31.16%	31.16%
$2,045	$118	$118	5.44%	5.44%
$2,162	-$500	$500	-30.10%	30.10%
$1,662	$695	$695	29.49%	29.49%
$2,357	$25	$25	1.05%	1.05%
$2,382				
	$337	$1,338	5.88%	66.08%
	ME	**MAE**	**MPE**	**MAPE**
	$84	$334	1.47%	16.52%

Table 27. CH-46D Holt's Linear Method CPFH Calculation

		α =	0.458089391	β =	0.761036009	m =	1
		Ft	**Error**	**|Error|**	**(Error/Yt)*100**		**|(Error/Yt)|*100**
L_t	**b_t**	**Holt's LM**	**Yt-Ft**	**|Yt-Ft|**	**Percent Error**		**Absolute Percent Error**
$1,408	$637						
$2,045	$637	$2,045	$0	$0	0.00%		0.00%
$2,444	$456	$2,682	-$519	$519	-24.03%		24.03%
$2,333	$24	$2,900	-$1,238	$1,238	-74.47%		74.47%
$2,357	$24	$2,357	$0	$0	0.00%		0.00%
$2,382	$25	$2,382	$0	$0	0.02%		0.02%
		$2,406					
			-$1,757	$1,758	-98.48%		98.52%
			ME	**MAE**	**MPE**		**MAPE**
			-$439	$439	-24.62%		24.63%

The summary statistics described in Chapter III are seen below the calculations in the three tables above. The key statistic in choosing the best forecasting model is usually the model with the lowest mean absolute percent error (MAPE). MAPE sums all of the absolute percentage errors and averages the values. Minimizing MAPE is essential to developing a model that will accurately forecast robust predictions. Theil's U was the determining factor in model selection as it incorporates MAPE with the observations in the current and future period to produce a number for model comparison. SES and Holt's linear method use parameters in the formulas that ultimately minimize MAPE. Excel Solver accomplishes this task by specifying the target cell and designating the changing cells.

The best forecasting model for the CH-46D helicopter, based on the goal of minimizing MAPE, is the MA3 model in Table 25. With a MAPE of 14.37%, the MA3 model out-performs SES and Holt's linear method. Additionally, all of the summary statistics are better for the MA3 model when compared to the other models. Holt's linear method would have a lower MAPE if not for FY00. The absolute percent error (APE) is unusually high during this year. It is important to note that this research only examines historical data from FY97-FY02. The results from the models would prove more accurate under normal conditions if more years of data were added to the forecast. Unfortunately, the VAMOSC system only reports Aircraft Type/Model/Series Report (ATMSR) data from FY97 to the present.

Table 28 displays the actual, budgeted, and forecasted CH-46D CPFH figures. Percentage deviations from actual data are given. The actual values versus budgeted values percent error is slightly better than the MA3. Since the budgeted values have a lower percent of error when compared to the forecasted models, the forecasted model values are worse than the Navy POM inputs. This does not imply that the forecasting methods are useless. In fact, the CH-46D results were an anomaly compared to the remainder of the rotary aircraft. For every other helicopter, the forecasting methods out-perform the budgeted values for FY00-FY02, when cumulative average of the percent of error is measured. Again, the developed models only use a few data points to minimize

MAPE. The summary statistics may improve if more data points are used to smooth out the fluctuations in the historical data.

Table 28. CH-46D Actual, Budgeted, Forecast Comparison

FY00	Budgeted	Actual	MA3 Forecast	SES Forecast	Holt's LM Forecast
	$ 1,795.55	$ 1,661.92	$ 1,871.42	$ 2,162.15	$ 2,899.60
Actuals vs. Budgeted	-8.04%				
Actuals vs. Forecast			-12.61%	-30.10%	-74.47%
FY01	**Budgeted**	**Actual**	**3YMA Forecast**	**SES Forecast**	**Holt's LM Forecast**
	$ 2,472.33	$ 2,357.09	$ 1,956.21	$ 1,661.92	$ 2,357.09
Actuals vs. Budgeted	-4.89%				
Actuals vs. Forecast			17.01%	29.49%	0.00%
FY02	**Budgeted**	**Actual**	**3YMA Forecast**	**SES Forecast**	**Holt's LM Forecast**
	$ 1,795.52	$ 2,381.99	$ 2,060.39	$ 2,357.09	$ 2,381.75
Actuals vs. Budgeted	24.62%				
Actuals vs. Forecast			13.50%	1.05%	0.01%

CH-53D Helicopter Results

CH-53D CES Trends.

The CH-53D and subsequent helicopters will follow a similar format as the CH-46D helicopter analysis and results section. Tables 29 through 34 show FY97-FY02 costs associated with the CH-53D helicopter. All costs reported in Tables 29 through 34 are reported in CY FY04 dollars. The data shows O&S costs by Major Claimant, total O&S cost, number of flying hours flown, and overall O&S CPFH. For the CH-53D helicopter, Commander in Chief U.S. Pacific Fleet (CINCPACFLT) is the only Major Claimant reporting costs.

Table 29. 1997 CH-53D Costs

CES	CINCPACFLT
1.0 Mission Personnel	$ 29,166,767
2.0 Unit-Level Consumption	$ 31,497,605
3.0 Intermediate Maintenance	$ 19,275,727
4.0 Depot Maintenance	$ 8,254,506
5.0 Contractor Support	$ 482,168
6.0 Sustaining Support	$ 13,448,275
7.0 Indirect Support	
Total Cost	$ 102,125,048
# of Aircraft	46
# Flying Hours	7,391
O&S CPFH	$ 13,817.49
Total Overall CH-53D O&S Cost	
$102,125,048	
Total Overall CH-53D # of Flying Hours	
7,710	
Total Overall CH-53D O&S CPFH	
$13,245.79	

Table 30. 1998 CH-53D Costs

CES	CINCPACFLT
1.0 Mission Personnel	$ 28,100,834
2.0 Unit-Level Consumption	$ 35,225,499
3.0 Intermediate Maintenance	$ 17,948,490
4.0 Depot Maintenance	$ 10,706,361
5.0 Contractor Support	$ 362,612
6.0 Sustaining Support	$ 8,632,336
7.0 Indirect Support	
Total Cost	$ 100,976,132
# of Aircraft	43
# Flying Hours	7712
O&S CPFH	$ 13,093.38
Total Overall CH-53D O&S Cost	
$100,976,132	
Total Overall CH-53D # of Flying Hours	
7,712	
Total Overall CH-53D O&S CPFH	
$13,093.38	

Table 31. 1999 CH-53D Costs

CES	CINCPACFLT
1.0 Mission Personnel	$ 25,335,437
2.0 Unit-Level Consumption	$ 33,464,752
3.0 Intermediate Maintenance	$ 9,567,772
4.0 Depot Maintenance	$ 9,857,387
5.0 Contractor Support	$ 320,115
6.0 Sustaining Support	$ 8,554,706
7.0 Indirect Support	
Total Cost	$ 87,100,169
# of Aircraft	44
# Flying Hours	7259
O&S CPFH	$ 11,998.92
Total Overall CH-53D O&S Cost	
$87,100,169	
Total Overall CH-53D # of Flying Hours	
7,259	
Total Overall CH-53D O&S CPFH	
$11,998.92	

Table 32. 2000 CH-53D Costs

CES	CINCPACFLT
1.0 Mission Personnel	$ 27,645,609
2.0 Unit-Level Consumption	$ 33,679,972
3.0 Intermediate Maintenance	$ 8,427,545
4.0 Depot Maintenance	$ 10,241,800
5.0 Contractor Support	$ 1,106,019
6.0 Sustaining Support	$ 6,727,288
7.0 Indirect Support	
Total Cost	$ 87,828,233
# of Aircraft	44
# Flying Hours	7500
O&S CPFH	$ 11,710.43
Total Overall CH-53D O&S Cost	
$87,828,233	
Total Overall CH-53D # of Flying Hours	
7,500	
Total Overall CH-53D O&S CPFH	
$11,710.43	

Table 33. 2001 CH-53D Costs

CES	CINCPACFLT
1.0 Mission Personnel	$ 25,207,092
2.0 Unit-Level Consumption	$ 32,821,213
3.0 Intermediate Maintenance	$ 6,671,362
4.0 Depot Maintenance	$ 6,128,628
5.0 Contractor Support	$ 2,048,318
6.0 Sustaining Support	$ 4,983,271
7.0 Indirect Support	$ 602,746
Total Cost	$ 78,462,630
# of Aircraft	38
# Flying Hours	7321
O&S CPFH	$ 10,717.47
Total Overall CH-53D O&S Cost	
$78,462,630	
Total Overall CH-53D # of Flying Hours	
7,321	
Total Overall CH-53D O&S CPFH	
$10,717.47	

Table 34. 2002 CH-53D Costs

CES	CINCPACFLT
1.0 Mission Personnel	$ 25,199,477
2.0 Unit-Level Consumption	$ 29,452,098
3.0 Intermediate Maintenance	$ 6,907,148
4.0 Depot Maintenance	$ 8,455,291
5.0 Contractor Support	$ 1,293,957
6.0 Sustaining Support	$ 10,408,409
7.0 Indirect Support	$ 549,565
Total Cost	$ 82,265,945
# of Aircraft	40
# Flying Hours	6883
O&S CPFH	$ 11,952.05
Total Overall CH-53D O&S Cost	
$82,265,945	
Total Overall CH-53D # of Flying Hours	
6,883	
Total Overall CH-53D O&S CPFH	
$11,952.05	

The components of the CH-53D CES were analyzed and computed as a percent of total O&S cost. The percentages were tallied by year and by Major Claimant. Table 35 shows the results of the O&S CES components as percentages of total O&S costs. The

Major Claimant results are not shown individually. Instead, Table 35 shows the results of the Major Claimants collectively.

Table 35. CH-53D CES Elements as a Percentage of Total O&S Cost

CES	1997	1998	1999	2000	2001	2002
1.0 Mission Personnel	28.56%	27.83%	29.09%	31.48%	32.13%	30.63%
2.0 Unit-Level Consumption	30.84%	34.88%	38.42%	38.35%	41.83%	35.80%
3.0 Intermediate Maintenance	18.87%	17.77%	10.98%	9.60%	8.50%	8.40%
4.0 Depot Maintenance	8.08%	10.60%	11.32%	11.66%	7.81%	10.28%
5.0 Contractor Support	0.47%	0.36%	0.37%	1.26%	2.61%	1.57%
6.0 Sustaining Support	13.17%	8.55%	9.82%	7.66%	6.35%	12.65%
7.0 Indirect Support	0.00%	0.00%	0.00%	0.00%	0.77%	0.67%

In addition to the table above, Figure 25 was created to portray the CES elements over time. The line chart makes it easier to examine any existing trends. Figure 25 shows the cost data as a percentage of the total cost. The costs are sorted by the seven CES components in Tables 29 through 34. The costs represent all Major Claimants. The CES components look relatively stable over time. Intermediate Maintenance has decreased approximately ten percent over time while Mission Personnel and Unit-Level Consumption have slightly increased.

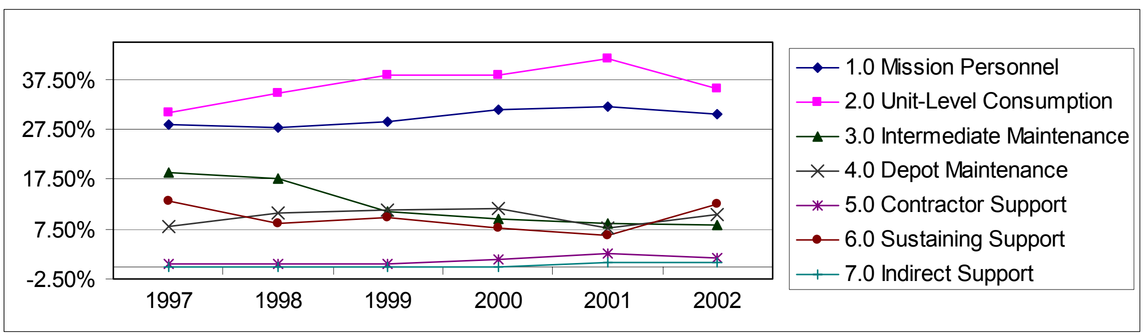

Figure 25. CH-53D CES Trends

CH-53D CPFH Trends.

An in-depth look at the components of CES 2.0 is necessary to determine the primary cost drivers for CPFH. Tables 36 through 41 illustrate the CPFH break-out for the CH-53D helicopter. Additionally, Figures 26 through 31 visually describe the CPFH percentage composition. Major increases or decreases to the CPFH components suggest cost drivers in developing trends.

Table 36. 1997 CH-53D CPFH

CES	CINCPACFLT
2.1 POL/Energy Consumables	$ 1,921,067
2.2 Consumable Materials/Repair Parts	$ 8,902,833
2.3 Depot Level Reparables	$ 16,447,401
Total Cost	$ 27,271,301
Total Overall CH-53D Flying Hour Costs	
$27,271,301	
Total Overall CH-53D CPFH	
$3,537.13	

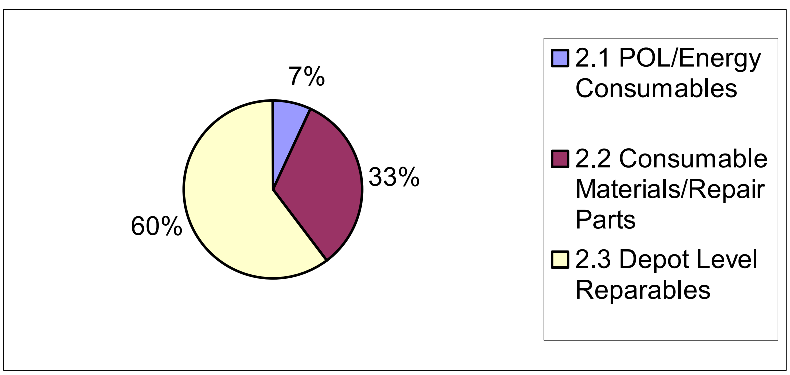

Figure 26. 1997 CH-53D CPFH Percentage Composition

Table 37. 1998 CH-53D CPFH

CES	CINCPACFLT
2.1 POL/Energy Consumables	$ 2,089,881
2.2 Consumable Materials/Repair Parts	$ 7,843,567
2.3 Depot Level Reparables	$ 21,637,807
Total Cost	$ 31,571,255
Total Overall CH-53D Flying Hour Costs	
$31,571,255	
Total Overall CH-53D CPFH	
$4,093.78	

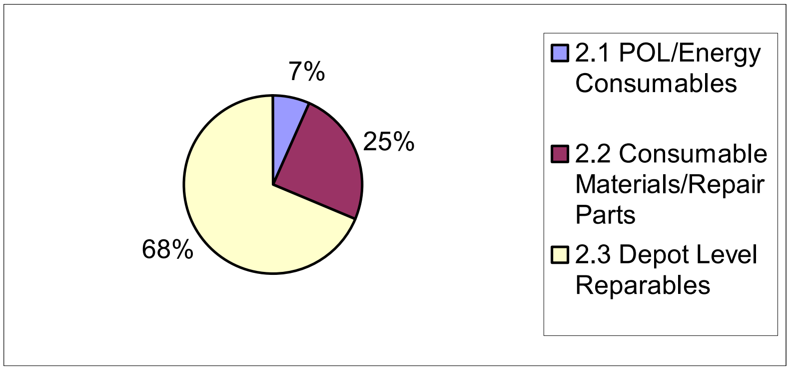

Figure 27. 1998 CH-53D CPFH Percentage Composition

Table 38. 1999 CH-53D CPFH

CES	CINCPACFLT
2.1 POL/Energy Consumables	$ 1,715,950
2.2 Consumable Materials/Repair Parts	$ 8,523,041
2.3 Depot Level Reparables	$ 20,037,604
Total Cost	$ 30,276,595
Total Overall CH-53D Flying Hour Costs	
$30,276,595	
Total Overall CH-53D CPFH	
$4,170.90	

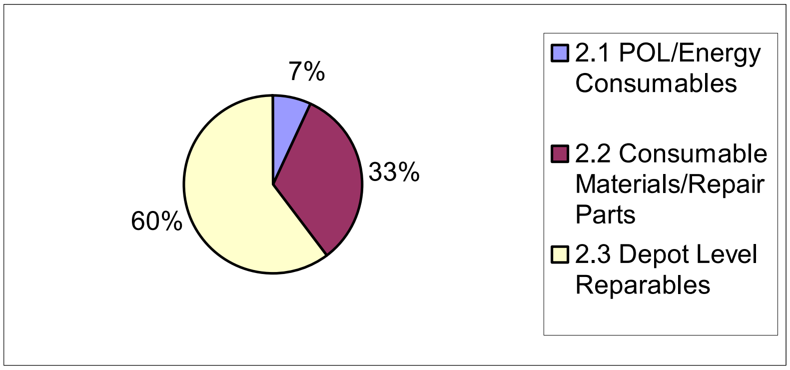

Figure 28. 1999 CH-53D CPFH Percentage Composition

Table 39. 2000 CH-53D CPFH

CES	CINCPACFLT
2.1 POL/Energy Consumables	$ 1,561,900
2.2 Consumable Materials/Repair Parts	$ 7,817,573
2.3 Depot Level Reparables	$ 20,853,674
Total Cost	$ 30,233,147

Total Overall CH-53D Flying Hour Costs
$30,233,147

Total Overall CH-53D CPFH
$4,031.09

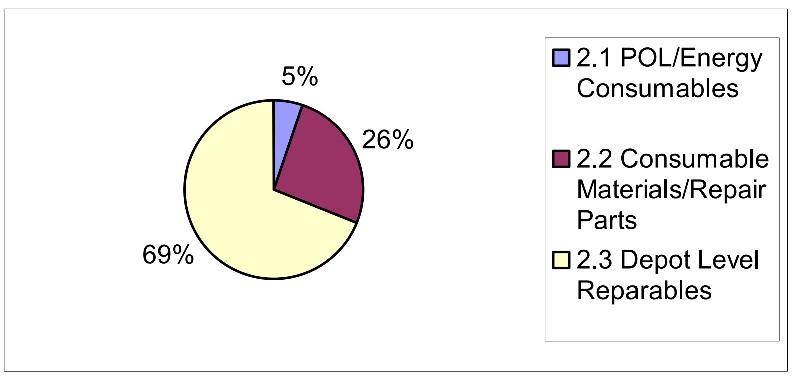

Figure 29. 2000 CH-53D CPFH Percentage Composition

Table 40. 2001 CH-53D CPFH

CES	CINCPACFLT
2.1 POL/Energy Consumables	$ 2,194,873
2.2 Consumable Materials/Repair Parts	$ 7,137,312
2.3 Depot Level Reparables	$ 21,966,213
Total Cost	$ 31,298,398
Total Overall CH-53D Flying Hour Costs $31,298,398	
Total Overall CH-53D CPFH $4,275.15	

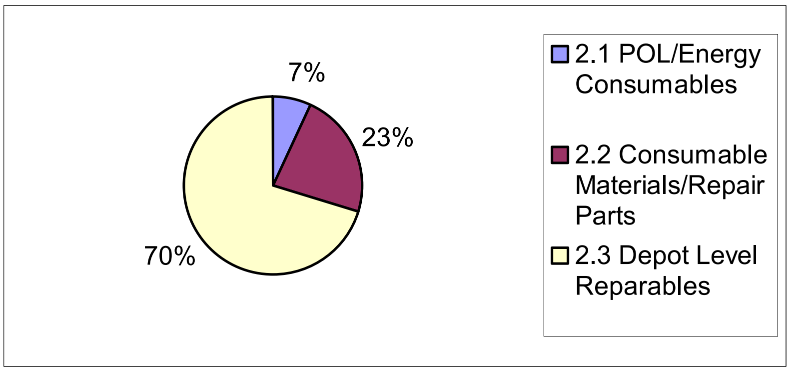

Figure 30. 2001 CH-53D CPFH Percentage Composition

Table 41. 2002 CH-53D CPFH

CES	CINCPACFLT
2.1 POL/Energy Consumables	$ 2,119,482
2.2 Consumable Materials/Repair Parts	$ 8,347,632
2.3 Depot Level Reparables	$ 18,118,579
Total Cost	$ 28,585,693
Total Overall CH-53D Flying Hour Costs $28,585,693	
Total Overall CH-53D CPFH $4,153.09	

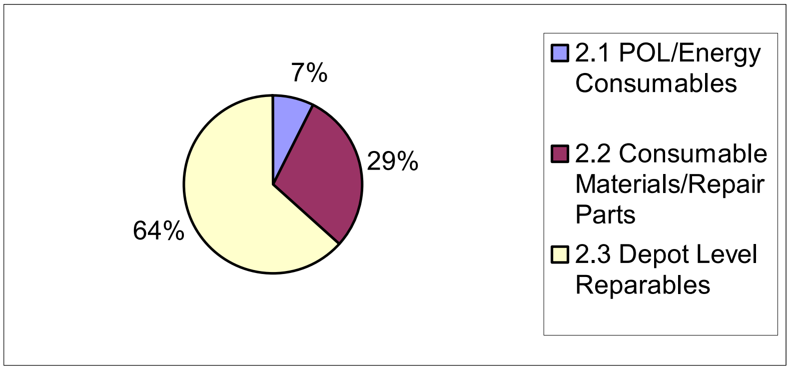

Figure 31. 2002 CH-53D CPFH Percentage Composition

The CPFH components for the CH-53D helicopter change over the course of time. The main cost drivers are DLRs and consumables. These cost drivers fluctuate throughout the six-year period. There are no apparent trends. DLRs may increase one year and decrease the next. The change in DLRs is inversely proportionate to consumables and repairable parts. Fuel is stationary. CPFH costs generally trend upward.

CH-53D Forecasting Results.

Cost data in Tables 36 through 41 is used to develop models for predicting future costs. Three forecasting techniques, as described in Chapter III, are utilized to build the three models. Table 42 shows the results from using the MA3 method with historical CPFH data. Table 43 displays the results from the SES method. Table 44 demonstrates Holt's linear method. Separate models are built for modeling Major Claimants but only the total costs are presented in this research.

Table 42. CH-53D MA3 CPFH Calculation

	Yt	Ft	Error	|Error|	(Error/Yt)*100	|(Error/Yt)|*100
Fiscal Year	CPFH	MA3	Yt-Ft	|Yt-Ft|	Percent Error	Absolute Percent Error
1997	$3,537					
1998	$4,094					
1999	$4,171					
2000	$4,031	$3,934	$97	$97	2.41%	2.41%
2001	$4,275	$4,099	$177	$177	4.13%	4.13%
2002	$4,153	$4,159	-$6	$6	-0.14%	0.14%
2003		$4,153				
Total			$268	$280	6.40%	6.68%
			ME	MAE	MPE	MAPE
			$89	$93	2.13%	2.23%

Table 43. CH-53D SES CPFH Calculation

α = 0.563331

Ft	Error	|Error|	(Error/Yt)*100	|(Error/Yt)|*100
SES	Yt-Ft	|Yt-Ft|	Percent Error	Absolute Percent Error
$3,537	$557	$557	13.60%	13.60%
$3,851	$320	$320	7.68%	7.68%
$4,031	$0	$0	0.00%	0.00%
$4,031	$244	$244	5.71%	5.71%
$4,169	-$15	$15	-0.37%	0.37%
$4,160				
	$229	$260	5.34%	6.08%
	ME	MAE	MPE	MAPE
	$57	$65	1.33%	1.52%

Table 44. CH-53D Holt's Linear Method CPFH Calculation

α = 0.792634797 β = 0.510260231 m = 1

		Ft	Error	|Error|	(Error/Yt)*100		|(Error/Yt)|*100
L_t	b_t	Holt's LM	Yt-Ft	|Yt-Ft|	Percent Error		Absolute Percent Error
$3,537	$557						
$4,094	$557	$4,094	$0	$0	0.00%		0.00%
$4,270	$363	$4,650	-$480	$480	-11.50%		11.50%
$4,156	$119	$4,633	-$602	$602	-14.93%		14.93%
$4,275	$119	$4,275	$0	$0	0.00%		0.00%
$4,203	$22	$4,394	-$241	$241	-5.81%		5.81%
		$4,225					
			-$1,323	$1,323	-32.24%		32.24%
			ME	MAE	MPE		MAPE
			-$331	$331	-8.06%		8.06%

The best forecasting model for the CH-53D helicopter, based on minimizing MAPE, is the SES model in Table 43. With a MAPE of 1.52%, the SES model out-performs MA3 and Holt's linear method. Additionally, all of the summary statistics are better for the SES model when compared to the other models. The best forecasting model for the CH-53D is not the same as the best CH-46D forecasting model. Analyses at the end of this chapter examine all forecasting methods for the helicopters studied. The model that consistently exhibits the best summary statistics and best Theil's U value is selected as the best model for use in future forecasting.

Table 45 displays the actual, budgeted, and forecasted CH-53D CPFH figures. Percentage deviations from actual data are given. The actual values versus budgeted values percent error is worse than all three of the forecasting models. Therefore, any of the forecasting models would have predicted a figure closer to the actual numbers. The SES model practically mirrors the actual dollar amounts for this helicopter. This close relationship between actual and forecasted values is desirable. It is important to keep the percent of error calculations as small as possible. Small percent deviations usually result in better approximations.

Table 45. CH-53D Actual, Budgeted, Forecast Comparison

FY00	Budgeted	Actual	MA3 Forecast	SES Forecast	Holt's LM Forecast
	$ 4,088.79	$ 4,031.09	$ 3,933.94	$ 4,031.09	$ 4,633.05
Actuals vs. Budgeted	-1.43%				
Actuals vs. Forecast			2.41%	0.00%	-14.93%
FY01	**Budgeted**	**Actual**	**3YMA Forecast**	**SES Forecast**	**Holt's LM Forecast**
	$ 4,789.91	$ 4,275.15	$ 4,098.59	$ 4,031.09	$ 4,275.15
Actuals vs. Budgeted	-12.04%				
Actuals vs. Forecast			4.13%	5.71%	0.00%
FY02	**Budgeted**	**Actual**	**3YMA Forecast**	**SES Forecast**	**Holt's LM Forecast**
	$ 4,786.09	$ 4,153.09	$ 4,159.05	$ 4,168.58	$ 4,394.39
Actuals vs. Budgeted	-15.24%				
Actuals vs. Forecast			-0.14%	-0.37%	-5.81%

MH-53E Helicopter Results

MH-53E CES Trends.

The MH-53E follows a similar format as the previous helicopters. Tables 46 through 51 show FY97-FY02 costs associated with the MH-53E helicopter. All costs reported in Tables 46 through 51 are reported in CY FY04 dollars. The data shows O&S costs by Major Claimant, total O&S cost, number of flying hours flown, and overall O&S CPFH.

It is interesting to note that the higher overall O&S costs associated with the MH-53E when compared to the CH-46D and the CH53D. The increased costs occur even though flight hours are not significantly greater than the number of flight hours for the first two helicopters. Higher Mission Personnel costs are mainly the cause of the increase to O&S costs. The MH-53E carries a larger number of personnel on board during its missions. The MH-53E carries two pilots and one to six aircrewman, depending on the mission performed.

Table 46. 1997 MH-53E Costs

CES	CINCLANTFLT	CHNAVRES
1.0 Mission Personnel	$ 56,843,689	$ 12,217,978
2.0 Unit-Level Consumption	$ 36,804,906	$ 8,583,029
3.0 Intermediate Maintenance	$ 6,311,829	
4.0 Depot Maintenance	$ 8,649,507	$ 771,620
5.0 Contractor Support	$ 177,584	$ 50,585
6.0 Sustaining Support	$ 17,940,700	$ 4,481,586
7.0 Indirect Support		
Total Cost	$ 126,728,215	$ 26,104,798
# of Aircraft	27	12
# Flying Hours	9,682	3,200
O&S CPFH	$ 13,089.05	$ 8,157.75
Total Overall MH-53E O&S Cost		
$152,833,013		
Total Overall MH-53E # of Flying Hours		
12,882		
Total Overall MH-53E O&S CPFH		
$11,864.07		

Table 47. 1998 MH-53E Costs

CES	CINCLANTFLT	CHNAVRES
1.0 Mission Personnel	$ 66,689,151	
2.0 Unit-Level Consumption	$ 47,676,520	$ 7,859,199
3.0 Intermediate Maintenance	$ 11,399,395	
4.0 Depot Maintenance	$ 9,866,713	$ 1,246,639
5.0 Contractor Support	$ 213,301	$ 94,919
6.0 Sustaining Support	$ 15,725,487	$ 6,845,723
7.0 Indirect Support		
Total Cost	$ 151,570,567	$ 16,046,480
# of Aircraft	27	12
# Flying Hours	9172	2586
O&S CPFH	$ 16,525.36	$ 6,205.14
Total Overall MH-53E O&S Cost		
$167,617,047		
Total Overall MH-53E # of Flying Hours		
11,758		
Total Overall MH-53E O&S CPFH		
$14,255.57		

Table 48. 1999 MH-53E Costs

CES	CINCLANTFLT	CHNAVRES
1.0 Mission Personnel	$ 64,365,776	
2.0 Unit-Level Consumption	$ 41,772,773	$ 9,679,650
3.0 Intermediate Maintenance	$ 10,209,711	
4.0 Depot Maintenance	$ 10,418,385	$ 2,669,918
5.0 Contractor Support	$ 200,732	$ 89,801
6.0 Sustaining Support	$ 13,986,037	$ 5,044,344
7.0 Indirect Support		
Total Cost	$ 140,953,414	$ 17,483,713
# of Aircraft	29	10
# Flying Hours	8771	2709
O&S CPFH	$ 16,070.39	$ 6,453.94
Total Overall MH-53E O&S Cost		
$158,437,127		
Total Overall MH-53E # of Flying Hours		
11,480		
Total Overall MH-53E O&S CPFH		
$13,801.14		

Table 49. 2000 MH-53E Costs

CES	CINCLANTFLT	CHNAVRES
1.0 Mission Personnel	$ 69,269,217	
2.0 Unit-Level Consumption	$ 45,515,303	$ 7,399,534
3.0 Intermediate Maintenance	$ 10,556,180	
4.0 Depot Maintenance	$ 7,935,370	$ 3,909,290
5.0 Contractor Support	$ 755,225	$ 55,213
6.0 Sustaining Support	$ 9,369,757	$ 1,716,610
7.0 Indirect Support		
Total Cost	$ 143,401,052	$ 13,080,647
# of Aircraft	29	6
# Flying Hours	7972	1494
O&S CPFH	$ 17,988.09	$ 8,755.45
Total Overall MH-53E O&S Cost		
$156,481,699		
Total Overall MH-53E # of Flying Hours		
9,466		
Total Overall MH-53E O&S CPFH		
$16,530.92		

Table 50. 2001 MH-53E Costs

CES	CINCLANTFLT	CHNAVRES
1.0 Mission Personnel	$ 69,438,808	
2.0 Unit-Level Consumption	$ 61,556,923	$ 7,466,943
3.0 Intermediate Maintenance	$ 11,156,943	
4.0 Depot Maintenance	$ 10,959,151	$ 2,333,764
5.0 Contractor Support	$ 1,100,770	$ 62,939
6.0 Sustaining Support	$ 9,014,819	$ 1,883,420
7.0 Indirect Support	$ 1,791,130	
Total Cost	$ 165,018,544	$ 11,747,066
# of Aircraft	29	7
# Flying Hours	8366	1068
O&S CPFH	$ 19,724.90	$ 10,999.13
Total Overall MH-53E O&S Cost		
$176,765,610		
Total Overall MH-53E # of Flying Hours		
9,434		
Total Overall MH-53E O&S CPFH		
$18,737.08		

Table 51. 2002 MH-53E Costs

CES	CINCLANTFLT	CINCPACFLT	CHNAVRES
1.0 Mission Personnel	$ 69,261,279		
2.0 Unit-Level Consumption	$ 58,193,282		$ 9,344,174
3.0 Intermediate Maintenance	$ 12,174,875		
4.0 Depot Maintenance	$ 13,297,521	$ 28,906	$ 3,574,266
5.0 Contractor Support	$ 1,240,199		$ 74,507
6.0 Sustaining Support	$ 4,968,865	$ 79,914	$ 787,750
7.0 Indirect Support	$ 1,473,657		
Total Cost	$ 160,609,678	$ 108,820	$ 13,780,697
# of Aircraft	28	0	8
# Flying Hours	9393	0	1564
O&S CPFH	$ 17,098.87		$ 8,811.19
Total Overall MH-53E O&S Cost			
$174,499,195			
Total Overall MH-53E # of Flying Hours			
10,957			
Total Overall MH-53E O&S CPFH			
$15,925.82			

The components of the MH-53E CES are analyzed and computed as a percent of total O&S cost. The percentages are tallied by year and by Major Claimant. Table 52 shows the results of the O&S CES components as percentages of total O&S costs. No apparent trends exist in the overall O&S CPFH. The costs do not steadily increase or decrease in any particular pattern. The Major Claimant results are not shown individually. Instead, Table 4-41 shows the results of the Major Claimants collectively.

Table 52. MH-53E CES Elements as a Percentage of Total O&S Cost

CES	1997	1998	1999	2000	2001	2002
1.0 Mission Personnel	45.19%	39.79%	40.63%	44.27%	39.28%	39.72%
2.0 Unit-Level Consumption	29.70%	33.13%	32.47%	33.82%	39.05%	38.73%
3.0 Intermediate Maintenance	4.13%	6.80%	6.44%	6.75%	6.31%	6.98%
4.0 Depot Maintenance	6.16%	6.63%	8.26%	7.57%	7.52%	9.67%
5.0 Contractor Support	0.15%	0.18%	0.18%	0.52%	0.66%	0.75%
6.0 Sustaining Support	14.67%	13.47%	12.01%	7.08%	6.17%	3.30%
7.0 Indirect Support	0.00%	0.00%	0.00%	0.00%	1.01%	0.85%

In addition to the table above, a line chart portrays the CES elements over time. The line chart makes it easier to examine any existing trends. Figure 32 shows the cost data as a percentage of the total cost. The costs are sorted by the seven CES components in Tables 46 through 51. The costs represent all Major Claimants. Overall, the CES components appear stable over time. Sustaining Support decreases approximately 11 percent while Unit-Level Consumption steadily increases the first few years and levels off in FY00. The increase in Unit-Level Consumption suggests an increase in CPFH.

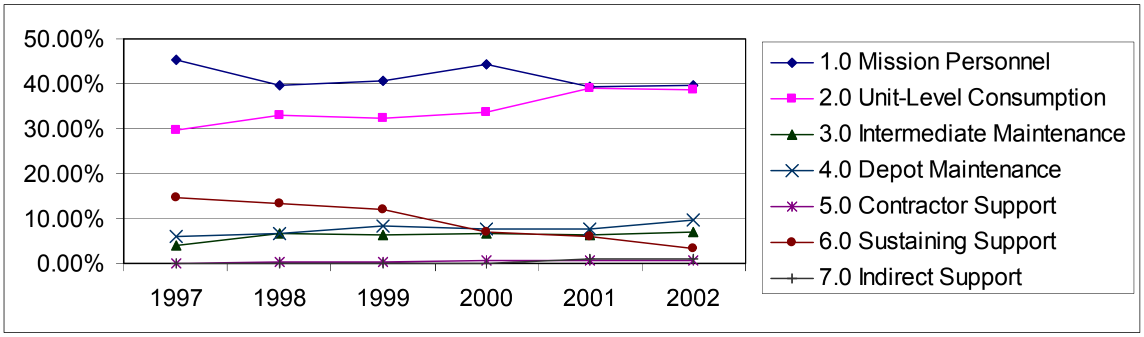

Figure 32. MH-53E CES Trends

MH-53E CPFH Trends.

An in-depth look at the components of CES 2.0 is necessary to determine the primary cost drivers are for CPFH. Tables 53 through 58 illustrate the CPFH break-down for the MH-53E helicopter. Additionally, Figures 33 through 38 depict the CPFH percentage composition. Major increases or decreases to the CPFH components suggest cost drivers in developing trends.

Table 53. 1997 MH-53E CPFH

CES	CINCLANTFLT	CHNAVRES
2.1 POL/Energy Consumables	$ 4,182,959	$ 1,312,960
2.2 Consumable Materials/Repair Parts	$ 9,105,020	$ 1,992,416
2.3 Depot Level Reparables	$ 17,382,129	$ 4,189,752
Total Cost	$ 30,670,108	$ 7,495,128
CPFH by Command	$ 3,168	$ 2,342
Total Overall MH-53E Flying Hour Costs		
$38,165,236		
Total Overall MH-53E CPFH		
$2,962.68		

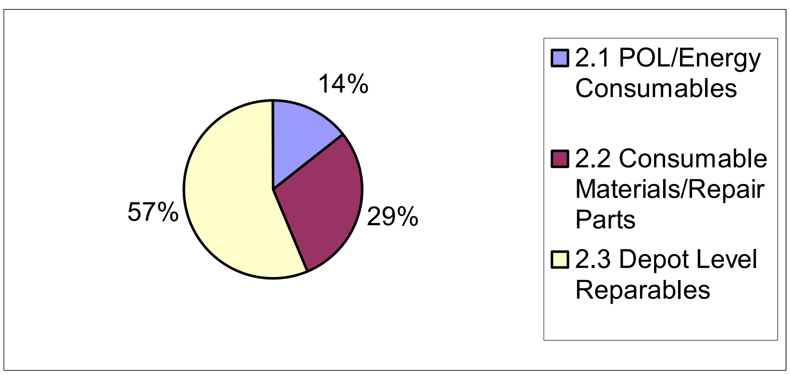

Figure 33. 1997 MH-53E CPFH Percentage Composition

Table 54. 1998 MH-53E CPFH

CES	CINCLANTFLT	CHNAVRES
2.1 POL/Energy Consumables	$ 4,520,617	$ 1,224,310
2.2 Consumable Materials/Repair Parts	$ 8,923,569	$ 2,040,955
2.3 Depot Level Reparables	$ 29,433,712	$ 3,906,394
Total Cost	$ 42,877,898	$ 7,171,659
CPFH by Command	$ 4,675	$ 2,773
Total Overall MH-53E Flying Hour Costs		
$50,049,557		
Total Overall MH-53E CPFH		
$4,256.64		

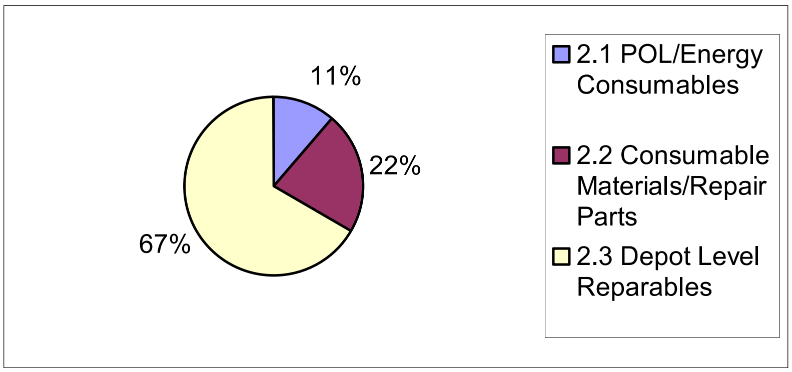

Figure 34. 1998 MH-53E CPFH Percentage Composition

Table 55. 1999 MH-53E CPFH

CES	CINCLANTFLT	CHNAVRES
2.1 POL/Energy Consumables	$ 4,275,038	$ 1,259,008
2.2 Consumable Materials/Repair Parts	$ 10,816,347	$ 2,451,374
2.3 Depot Level Reparables	$ 22,934,298	$ 5,106,986
Total Cost	$ 38,025,683	$ 8,817,368
CPFH by Command	$ 4,335	$ 3,255
Total Overall MH-53E Flying Hour Costs		
$46,843,051		
Total Overall MH-53E CPFH		
$4,080.41		

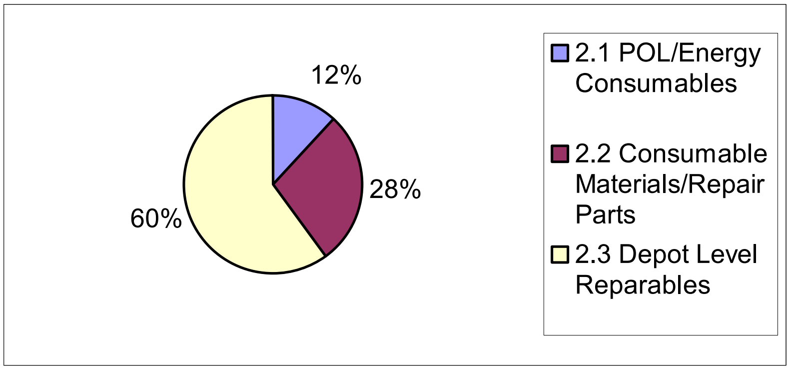

Figure 35. 1999 MH-53E CPFH Percentage Composition

Table 56. 2000 MH-53E CPFH

CES	CINCLANTFLT	CHNAVRES
2.1 POL/Energy Consumables	$ 2,907,500	$ 611,031
2.2 Consumable Materials/Repair Parts	$ 11,774,360	$ 1,838,382
2.3 Depot Level Reparables	$ 26,587,805	$ 4,197,149
Total Cost	$ 41,269,665	$ 6,646,562
CPFH by Command	$ 5,177	$ 4,449
Total Overall MH-53E Flying Hour Costs		
$47,916,227		
Total Overall MH-53E CPFH		
$5,061.93		

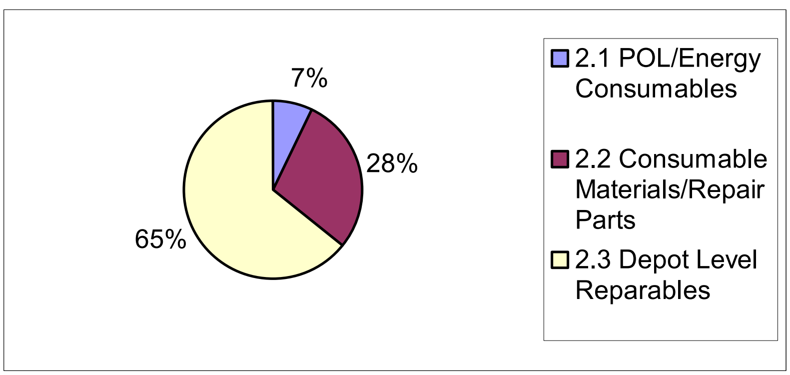

Figure 36. 2000 MH-53E CPFH Percentage Composition

Table 57. 2001 MH-53E CPFH

CES	CINCLANTFLT	CHNAVRES
2.1 POL/Energy Consumables	$ 4,325,295	$ 656,820
2.2 Consumable Materials/Repair Parts	$ 15,132,885	$ 1,770,659
2.3 Depot Level Reparables	$ 39,601,613	$ 4,755,174
Total Cost	$ 59,059,793	$ 7,182,653
CPFH by Command	$ 7,060	$ 6,725

Total Overall MH-53E Flying Hour Costs
$66,242,446

Total Overall MH-53E CPFH
$7,021.67

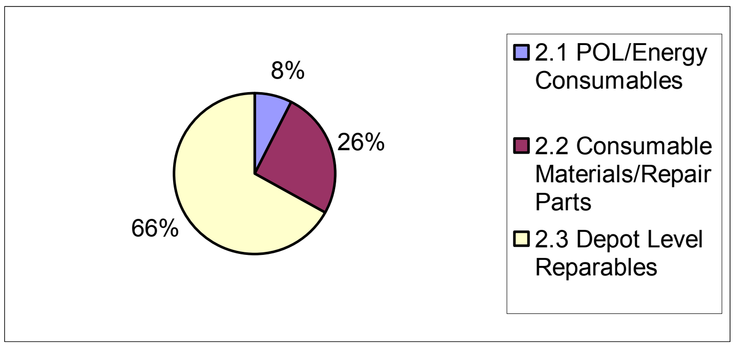

Figure 37. 2001 MH-53E CPFH Percentage Composition

Table 58. 2002 MH-53E CPFH

CES	CINCLANTFLT	CHNAVRES
2.1 POL/Energy Consumables	$ 5,773,517	$ 986,868
2.2 Consumable Materials/Repair Parts	$ 13,870,857	$ 2,234,659
2.3 Depot Level Reparables	$ 37,514,937	$ 5,963,769
Total Cost	$ 57,159,311	$ 9,185,296
CPFH by Command	$ 6,085	$ 5,873

Total Overall MH-53E Flying Hour Costs
$66,344,607

Total Overall MH-53E CPFH
$6,055.00

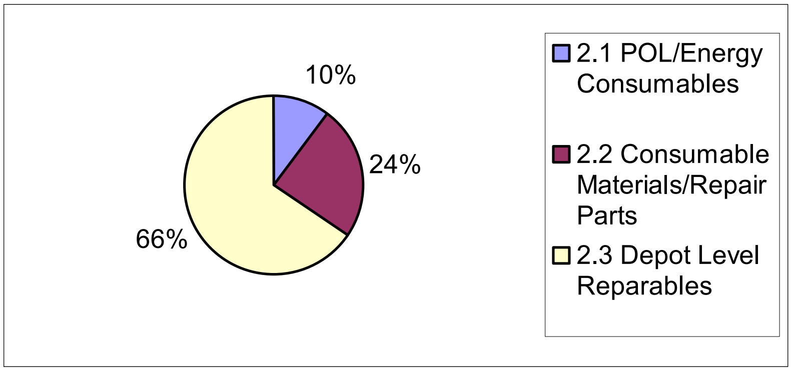

Figure 38. 2002 MH-53E CPFH Percentage Composition

The CPFH components for the MH-53E helicopter change over the course of time. The main cost driver is DLRs. In FY97 and FY99, DLRs are significantly lower. Consumables and repair parts only change by a few percentage points. Fuel costs are higher than the CH-46D and CH-53D. Fuel costs also constitute a greater percentage of CPFH. The reason the MH-53E carries greater fuel costs than the other helicopters stems from the type of mission performed. The MH-53E has a greater capacity for fuel than the CH-46D and the CH-53D. The MH-53E is also described as a heavy lift multi-engine helicopter, whereas, the other two helicopters are classified as medium lift helicopters. CPFH costs generally trend upward.

MH-53E Forecasting Results.

Cost data in Tables 53 through 58 is used to develop models for predicting future costs. Three forecasting techniques, as described in Chapter III, are utilized to build the three models. Table 59 shows the results from using the MA3 method with historical CPFH data. Table 60 displays the results from the SES method. Table 61 calculates Holt's linear method.

Table 59. MH-53E MA3 CPFH Calculation

	Yt	Ft	Error	|Error|	(Error/Yt)*100	|(Error/Yt)|*100
Fiscal Year	CPFH	MA3	Yt-Ft	|Yt-Ft|	Percent Error	Absolute Percent Error
1997	$2,963					
1998	$4,257					
1999	$4,080					
2000	$5,062	$3,767	$1,295	$1,295	25.59%	25.59%
2001	$7,022	$4,466	$2,555	$2,555	36.39%	36.39%
2002	$6,055	$5,388	$667	$667	11.02%	11.02%
2003		$6,046				
Total			$4,518	$4,518	73.00%	73.00%
			ME	MAE	MPE	MAPE
			$1,506	$1,506	24.33%	24.33%

Table 60. MH-53E SES CPFH Calculation

α = 0.863803

Ft	Error	|Error|	(Error/Yt)*100	|(Error/Yt)|*100
SES	Yt-Ft	|Yt-Ft|	Percent Error	Absolute Percent Error
$2,963	$1,294	$1,294	30.40%	30.40%
$4,080	$0	$0	0.00%	0.00%
$4,080	$982	$982	19.39%	19.39%
$4,928	$2,093	$2,093	29.81%	29.81%
$6,737	-$682	$682	-11.26%	11.26%
$6,148				
	$2,393	$3,757	37.95%	60.46%
	ME	MAE	MPE	MAPE
	$598	$939	9.49%	15.12%

Table 61. MH-53E Holt's Linear Method CPFH Calculation

α = 0.398752466 β = 1 m = 1

		Ft	Error	|Error|	(Error/Yt)*100	|(Error/Yt)|*100
L_t	b_t	Holt's LM	Yt-Ft	|Yt-Ft|	Percent Error	Absolute Percent Error
$2,963	$1,294					
$4,257	$1,294	$4,257	$0	$0	0.00%	0.00%
$4,964	$708	$5,551	-$1,470	$1,470	-36.03%	36.03%
$5,429	$464	$5,672	-$610	$610	-12.05%	12.05%
$6,343	$914	$5,893	$1,128	$1,128	16.07%	16.07%
$6,778	$435	$7,258	-$1,203	$1,203	-19.86%	19.86%
		$7,213				
			-$2,154	$4,411	-51.87%	84.02%
			ME	MAE	MPE	MAPE
			-$539	$1,103	-12.97%	21.00%

The best forecasting model for the MH-53E helicopter, with respect to MAPE, is the SES model in Table 60. With a MAPE of 15.12%, the SES model out-performs MA3 and Holt's linear method. Additionally, the majority of the summary statistics are better for the SES model when compared to the other models. The summary statistics for the SES model and Holt's linear model are based on the last four years of data. The data for FY97 and FY98 are not used in the computation of MAPE because these values are used to initialize the forecast.

Table 62 displays the actual, budgeted, and forecasted MH-53E CPFH figures. Percentage deviations from actual data are given. The actual values versus budgeted values percent error is worse than all three of the forecasting models. Therefore, any of the forecasting models would have predicted a figure closer to the actual numbers.

Table 62. MH-53E Actual, Budgeted, Forecast Comparison

FY00	Budgeted	Actual	MA3 Forecast	SES Forecast	Holt's LM Forecast
	$ 3,560.46	$ 5,061.93	$ 3,766.57	$ 4,080.41	$ 5,672.07
Actuals vs. Budgeted	29.66%				
Actuals vs. Forecast			25.59%	19.39%	-12.05%
FY01	**Budgeted**	**Actual**	**3YMA Forecast**	**SES Forecast**	**Holt's LM Forecast**
	$ 4,778.48	$ 7,021.67	$ 4,466.32	$ 4,928.25	$ 5,893.20
Actuals vs. Budgeted	31.95%				
Actuals vs. Forecast			36.39%	29.81%	16.07%
FY02	**Budgeted**	**Actual**	**3YMA Forecast**	**SES Forecast**	**Holt's LM Forecast**
	$ 4,810.08	$ 6,055.00	$ 5,388.00	$ 6,736.55	$ 7,257.58
Actuals vs. Budgeted	20.56%				
Actuals vs. Forecast			11.02%	-11.26%	-19.86%

SH-60F Helicopter Results

SH-60F CES Trends.

The results for the SH-60F helicopter are discussed in next. Tables 63 through 68 show FY97-FY02 costs associated with the SH-60F helicopter. All costs reported in

Tables 63 through 68 are in CY FY04 dollars. The data shows O&S costs by Major Claimant, total O&S cost, number of flying hours flown, and overall O&S CPFH.

Table 63. 1997 SH-60F Costs

CES	CINCLANTFLT	CINCPACFLT
1.0 Mission Personnel	$ 39,005,382	$ 56,959,232
2.0 Unit-Level Consumption	$ 22,989,305	$ 32,064,406
3.0 Intermediate Maintenance	$ 4,755,545	$ 7,521,627
4.0 Depot Maintenance	$ 2,651,482	$ 8,825,840
5.0 Contractor Support	$ 215,254	$ 304,584
6.0 Sustaining Support	$ 11,997,482	$ 16,793,522
7.0 Indirect Support		
Total Cost	$ 81,614,450	$ 122,469,211
# of Aircraft	28	45
# Flying Hours	11,795	16,163
O&S CPFH	$ 6,919.41	$ 7,577.13
Total Overall SH-60F O&S Cost		
$204,083,661		
Total Overall SH-60F # of Flying Hours		
27,958		
Total Overall SH-60F O&S CPFH		
$7,299.65		

Table 64. 1998 SH-60F Costs

CES	CINCLANTFLT	CINCPACFLT
1.0 Mission Personnel	$ 33,528,082	$ 55,860,070
2.0 Unit-Level Consumption	$ 13,104,707	$ 40,928,598
3.0 Intermediate Maintenance	$ 3,207,025	$ 7,572,353
4.0 Depot Maintenance	$ 2,132,229	$ 11,953,181
5.0 Contractor Support	$ 233,565	$ 362,612
6.0 Sustaining Support	$ 4,096,258	$ 5,850,033
7.0 Indirect Support		
Total Cost	$ 56,301,866	$ 122,526,847
# of Aircraft	27	44
# Flying Hours	10781	15943
O&S CPFH	$ 5,222.32	$ 7,685.31
Total Overall SH-60F O&S Cost		
$178,828,713		
Total Overall SH-60F # of Flying Hours		
26,724		
Total Overall SH-60F O&S CPFH		
$6,691.69		

Table 65. 1999 SH-60F Costs

CES	CINCLANTFLT	CINCPACFLT	CHNAVRES
1.0 Mission Personnel	$ 32,483,039	$ 55,088,590	$ 1,669,486
2.0 Unit-Level Consumption	$ 23,333,040	$ 33,843,834	
3.0 Intermediate Maintenance	$ 4,393,060	$ 5,932,600	
4.0 Depot Maintenance	$ 6,052,291	$ 12,178,289	$ 1,500,215
5.0 Contractor Support	$ 236,653	$ 390,899	
6.0 Sustaining Support	$ 4,219,580	$ 6,747,667	$ 138,257
7.0 Indirect Support			
Total Cost	$ 70,717,663	$ 114,181,879	$ 3,307,958
# of Aircraft	27	43	2
# Flying Hours	10413	15900	0
O&S CPFH	$ 6,791.29	$ 7,181.25	

Total Overall SH-60F O&S Cost
$188,207,500

Total Overall SH-60F # of Flying Hours
26,313

Total Overall SH-60F O&S CPFH
$7,152.64

Table 66. 2000 SH-60F Costs

CES	CINCLANTFLT	CINCPACFLT	CHNAVRES
1.0 Mission Personnel	$ 34,202,626	$ 59,269,801	$ 4,401,506
2.0 Unit-Level Consumption	$ 25,251,308	$ 43,207,145	$ 1,668,421
3.0 Intermediate Maintenance	$ 2,925,747	$ 6,615,052	
4.0 Depot Maintenance	$ 5,028,777	$ 8,508,045	$ 615,758
5.0 Contractor Support	$ 252,103	$ 1,554,232	$ 40,628
6.0 Sustaining Support	$ 3,306,792	$ 5,285,892	$ 757,591
7.0 Indirect Support			
Total Cost	$ 70,967,353	$ 124,440,167	$ 7,483,904
# of Aircraft	25	43	4
# Flying Hours	10136	15187	434
O&S CPFH	$ 7,001.51	$ 8,193.86	$ 17,244.02

Total Overall SH-60F O&S Cost
$202,891,424

Total Overall SH-60F # of Flying Hours
25,757

Total Overall SH-60F O&S CPFH
$7,877.14

Table 67. 2001 SH-60F Costs

CES	CINCLANTFLT	CINCPACFLT	CHNAVRES
1.0 Mission Personnel	$ 35,405,954	$ 59,771,192	$ 6,461,078
2.0 Unit-Level Consumption	$ 33,058,456	$ 43,078,581	$ 4,605,138
3.0 Intermediate Maintenance	$ 5,536,128	$ 6,160,979	
4.0 Depot Maintenance	$ 4,501,625	$ 8,142,394	$ 1,388,551
5.0 Contractor Support	$ 408,819	$ 1,737,081	$ 62,302
6.0 Sustaining Support	$ 3,739,708	$ 6,153,958	$ 753,848
7.0 Indirect Support	$ 827,403	$ 1,102,610	$ 123,296
Total Cost	$ 83,478,093	$ 126,146,795	$ 13,394,213
# of Aircraft	25	41	6
# Flying Hours	10079	15665	2109
O&S CPFH	$ 8,282.38	$ 8,052.78	$ 6,350.98
Total Overall SH-60F O&S Cost			
$223,019,101			
Total Overall SH-60F # of Flying Hours			
27,853			
Total Overall SH-60F O&S CPFH			
$8,007.00			

Table 68. 2002 SH-60F Costs

CES	CINCLANTFLT	CINCPACFLT	CHNAVRES
1.0 Mission Personnel	$ 36,437,624	$ 61,216,011	$ 6,335,993
2.0 Unit-Level Consumption	$ 34,893,164	$ 44,287,743	$ 4,119,349
3.0 Intermediate Maintenance	$ 4,406,628	$ 9,663,191	
4.0 Depot Maintenance	$ 3,853,171	$ 6,546,443	$ 1,049,535
5.0 Contractor Support	$ 718,736	$ 1,231,714	$ 73,240
6.0 Sustaining Support	$ 5,779,458	$ 8,565,140	$ 987,513
7.0 Indirect Support	$ 986,812	$ 1,107,279	$ 131,236
Total Cost	$ 87,075,593	$ 132,617,521	$ 12,696,866
# of Aircraft	24	41	6
# Flying Hours	11272	15981	2066
O&S CPFH	$ 7,724.95	$ 8,298.45	$ 6,145.63
Total Overall SH-60F O&S Cost			
$232,389,980			
Total Overall SH-60F # of Flying Hours			
29,319			
Total Overall SH-60F O&S CPFH			
$7,926.26			

The overall O&S CPFH represents the total O&S costs associated with the helicopter for that particular year divided by the number of flying hours. This number gives a good indication if costs are increasing or decreasing. The costs for the SH-60F increase modestly over time. Because the numbers are in CY FY04 dollars, the effects of inflation are negated. Therefore, the numbers give a true indication of whether or not weapon system costs are escalating.

The components of the SH-60F CES are analyzed and computed as a percent of total O&S cost. The percentages are tallied by year and by Major Claimant. Table 69 shows the results of the O&S CES components as percentages of total O&S costs. The Major Claimant results are not shown individually. Instead, Table 69 shows the results of the Major Claimants collectively.

Table 69. SH-60F CES Elements as a Percentage of Total O&S Cost

CES	1997	1998	1999	2000	2001	2002
1.0 Mission Personnel	47.02%	49.99%	47.42%	48.24%	45.57%	44.75%
2.0 Unit-Level Consumption	26.98%	30.22%	30.38%	34.56%	36.20%	35.85%
3.0 Intermediate Maintenance	6.02%	6.03%	5.49%	4.70%	5.24%	6.05%
4.0 Depot Maintenance	5.62%	7.88%	10.48%	6.98%	6.29%	4.93%
5.0 Contractor Support	0.25%	0.33%	0.33%	0.91%	0.99%	0.87%
6.0 Sustaining Support	14.11%	5.56%	5.90%	4.61%	4.77%	6.60%
7.0 Indirect Support	0.00%	0.00%	0.00%	0.00%	0.92%	0.96%

In addition to the table above, Figure 39 depicts the CES elements over time. The line chart makes it easier to examine existing trends. Figure 39 shows the cost data as a percentage of the total cost. The costs are sorted by the seven CES components in Tables 63 through 68. The costs represent all Major Claimants. Collectively, the CES components appear stable over time. Unit-Level Consumption increases almost ten percent over the period studied. Mission Personnel decreases slightly over the period studied. The increase in Unit-Level Consumption suggests an increase in CPFH.

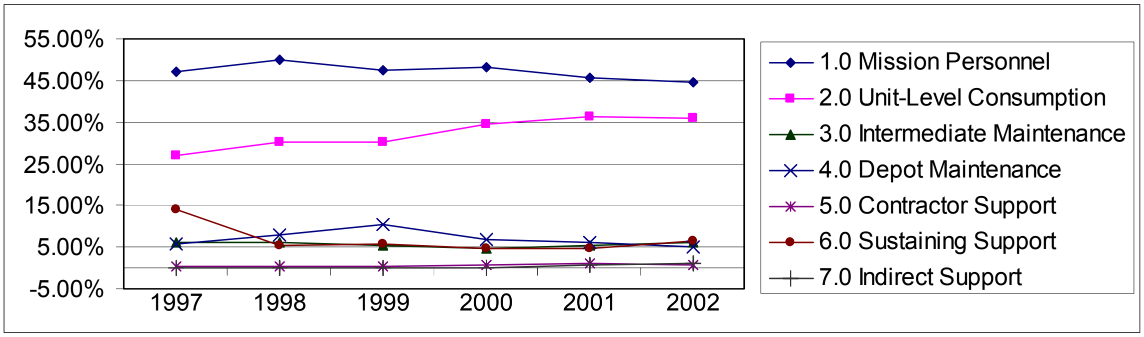

Figure 39. SH-60F CES Trends

SH-60F CPFH Trends.

An in-depth look at the components of CES 2.0 is necessary to determine the primary cost drivers are for CPFH. Tables 70 through 75 illustrate the CPFH break-down for the SH-60F helicopter. Additionally, Figures 40 through 45 display the CPFH percentage composition. Major increases or decreases to the CPFH components suggest cost drivers in developing trends.

Table 70. 1997 SH-60F CPFH

CES	CINCLANTFLT		CINCPACFLT	
2.1 POL/Energy Consumables	$	1,365,887	$	1,859,340
2.2 Consumable Materials/Repair Parts	$	5,207,265	$	8,157,352
2.3 Depot Level Reparables	$	10,928,417	$	14,052,815
Total Cost	$	17,501,569	$	24,069,507
CPFH by Command	$	1,484	$	1,489
Total Overall SH-60F Flying Hour Costs $41,571,076				
Total Overall SH-60F CPFH $1,486.91				

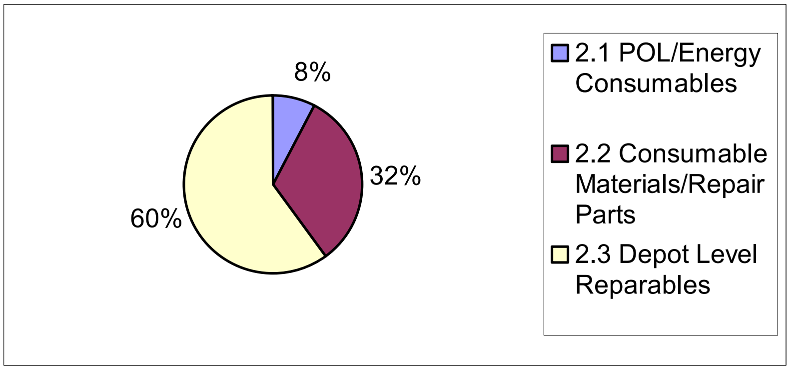

Figure 40. 1997 SH-60F CPFH Percentage Composition

Table 71. 1998 SH-60F CPFH

CES	CINCLANTFLT	CINCPACFLT
2.1 POL/Energy Consumables	$ 1,440,338	$ 2,148,666
2.2 Consumable Materials/Repair Parts	$ 6,161,125	$ 8,224,042
2.3 Depot Level Reparables	$ 3,884,662	$ 24,909,536
Total Cost	$ 11,486,125	$ 35,282,244
CPFH by Command	$ 1,065	$ 2,213

Total Overall SH-60F Flying Hour Costs
$46,768,369

Total Overall SH-60F CPFH
$1,750.05

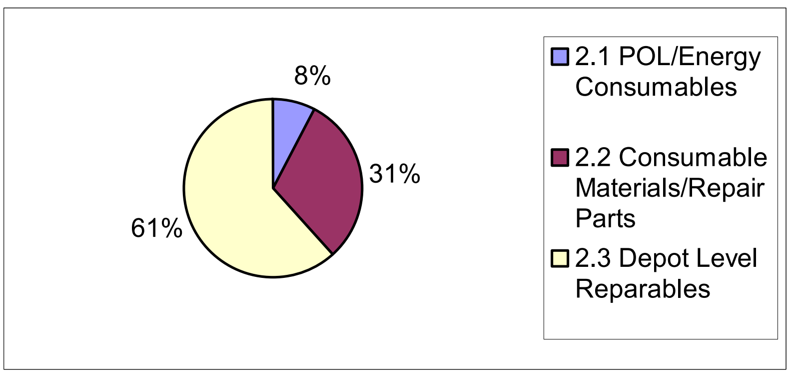

Figure 41. 1998 SH-60F CPFH Percentage Composition

Table 72. 1999 SH-60F CPFH

CES	CINCLANTFLT	CINCPACFLT
2.1 POL/Energy Consumables	$ 1,349,824	$ 1,919,572
2.2 Consumable Materials/Repair Parts	$ 5,597,166	$ 8,292,754
2.3 Depot Level Reparables	$ 13,500,596	$ 19,254,859
Total Cost	$ 20,447,586	$ 29,467,185
CPFH by Command	$ 1,964	$ 1,853
Total Overall SH-60F Flying Hour Costs		
$49,914,771		
Total Overall SH-60F CPFH		
$1,896.96		

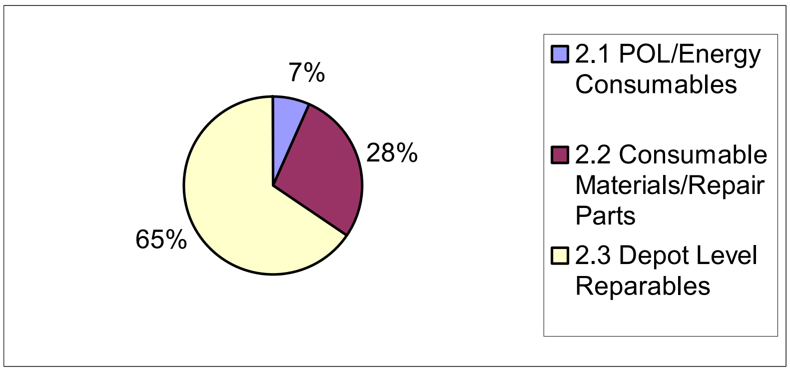

Figure 42. 1999 SH-60F CPFH Percentage Composition

Table 73. 2000 SH-60F CPFH

CES	CINCLANTFLT	CINCPACFLT	CHNAVRES
2.1 POL/Energy Consumables	$ 975,288	$ 1,496,086	$ 44,615
2.2 Consumable Materials/Repair Parts	$ 5,384,224	$ 9,230,949	$ 543,403
2.3 Depot Level Reparables	$ 16,166,138	$ 27,432,080	$ 921,457
Total Cost	$ 22,525,650	$ 38,159,115	$ 1,509,475
CPFH by Command	$ 2,222	$ 2,513	$ 3,478
Total Overall SH-60F Flying Hour Costs			
$62,194,240			
Total Overall SH-60F CPFH			
$2,414.65			

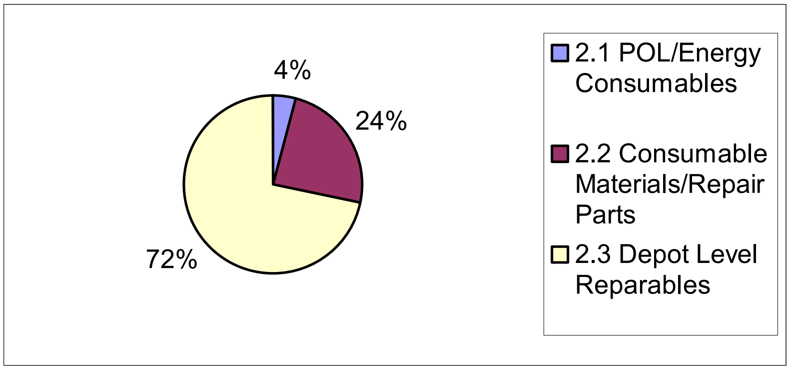

Figure 43. 2000 SH-60F CPFH Percentage Composition

Table 74. 2001 SH-60F CPFH

CES	CINCLANTFLT	CINCPACFLT	CHNAVRES
2.1 POL/Energy Consumables	$ 1,606,971	$ 2,371,632	$ 293,573
2.2 Consumable Materials/Repair Parts	$ 7,558,804	$ 8,934,878	$ 1,426,211
2.3 Depot Level Reparables	$ 21,295,123	$ 27,486,924	$ 2,340,885
Total Cost	$ 30,460,898	$ 38,793,434	$ 4,060,669
CPFH by Command	$ 3,022	$ 2,476	$ 1,925

Total Overall SH-60F Flying Hour Costs
$73,315,001

Total Overall SH-60F CPFH
$2,632.21

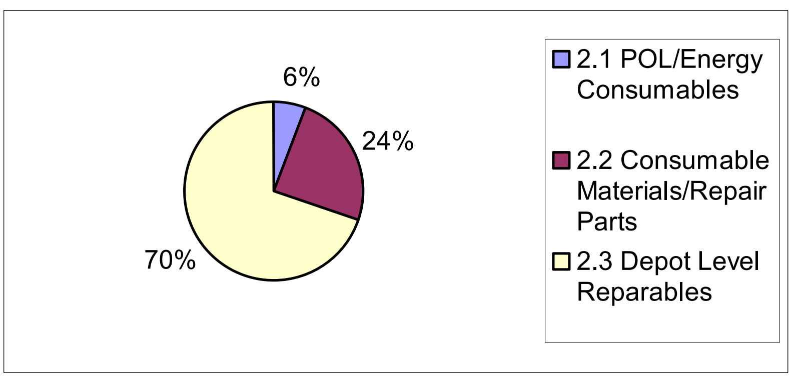

Figure 44. 2001 SH-60F CPFH Percentage Composition

Table 75. 2002 SH-60F CPFH

CES	CINCLANTFLT	CINCPACFLT	CHNAVRES
2.1 POL/Energy Consumables	$ 1,734,948	$ 2,341,435	$ 293,930
2.2 Consumable Materials/Repair Parts	$ 8,940,912	$ 10,823,468	$ 1,138,573
2.3 Depot Level Reparables	$ 23,404,062	$ 30,098,816	$ 2,602,615
Total Cost	$ 34,079,922	$ 43,263,719	$ 4,035,118
CPFH by Command	$ 3,023	$ 2,707	$ 1,953
Total Overall SH-60F Flying Hour Costs			
$81,378,759			
Total Overall SH-60F CPFH			
$2,775.63			

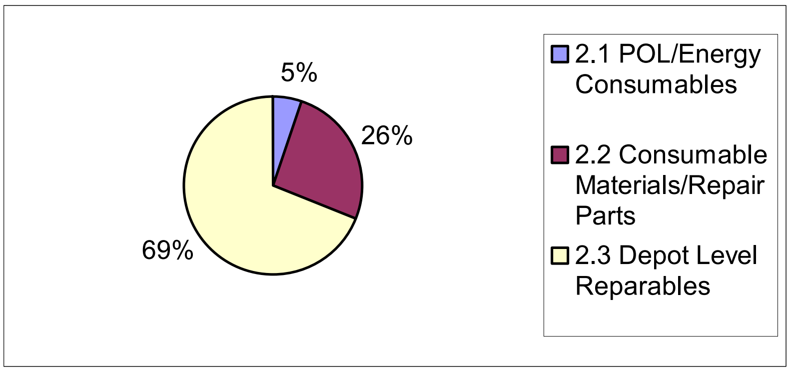

Figure 45. 2002 SH-60F CPFH Percentage Composition

The CPFH components for the SH-60F helicopter change over the course of time. The main cost driver is DLRs. As time goes by, DLRs constitute a greater percentage of the CPFH make-up. Consumables and repair parts decrease over time while fuel stays relatively stable. CPFH costs trend upward. In fact, CPFH increases every year during the period studied.

SH-60F Forecasting Results.

Cost data in Tables 76 through 78 is used to develop models for predicting future costs. Three forecasting techniques, as described in Chapter III, are utilized to build the three models. Table 76 shows the results from using the MA3 method with historical

CPFH data. Table 77 displays the results from the SES method. Table 78 calculates Holt's linear method.

Table 76. SH-60F MA3 CPFH Calculation

	Yt	Ft	Error	|Error|	(Error/Yt)*100	|(Error/Yt)|*100
Fiscal Year	CPFH	MA3	Yt-Ft	|Yt-Ft|	Percent Error	Absolute Percent Error
1997	$1,487					
1998	$1,750					
1999	$1,897					
2000	$2,415	$1,711	$703	$703	29.13%	29.13%
2001	$2,632	$2,021	$612	$612	23.24%	23.24%
2002	$2,776	$2,315	$461	$461	16.61%	16.61%
2003		$2,607				
Total			$1,776	$1,776	68.98%	68.98%
			ME	MAE	MPE	MAPE
			$592	$592	22.99%	22.99%

Table 77. SH-60F SES CPFH Calculation

α = 1

Ft	Error	|Error|	(Error/Yt)*100	|(Error/Yt)|*100
SES	Yt-Ft	|Yt-Ft|	Percent Error	Absolute Percent Error
$1,487	$263	$263	15.04%	15.04%
$1,750	$147	$147	7.74%	7.74%
$1,897	$518	$518	21.44%	21.44%
$2,415	$218	$218	8.27%	8.27%
$2,632	$143	$143	5.17%	5.17%
$2,776				
	$1,026	$1,026	42.62%	42.62%
	ME	MAE	MPE	MAPE
	$256	$256	10.65%	10.65%

Table 78. SH-60F Holt's Linear Method CPFH Calculation

		α =	0	β =	0.215012888	m =	1
		Ft	**Error**	**|Error|**	**(Error/Yt)*100**		**|(Error/Yt)|*100**
L_t	**b_t**	**Holt's LM**	**Yt-Ft**	**|Yt-Ft|**	**Percent Error**		**Absolute Percent Error**
$1,487	$263						
$1,750	$263	$1,750	$0	$0	0.00%		0.00%
$2,013	$263	$2,013	-$116	$116	-6.13%		6.13%
$2,276	$263	$2,276	$138	$138	5.73%		5.73%
$2,539	$263	$2,539	$93	$93	3.52%		3.52%
$2,803	$263	$2,803	-$27	$27	-0.97%		0.97%
		$3,066					
			$88	$374	2.15%		16.35%
			ME	**MAE**	**MPE**		**MAPE**
			$22	$94	0.54%		4.09%

The best forecasting model for the SH-60F helicopter, based on minimizing MAPE, is Holt's linear model in Table 78. With a MAPE of 4.09%, Holt's linear model out-performs MA3 and SES. Additionally, all of the summary statistics are better for the Holt's linear method model when compared with the other models. The summary statistics for the SES model and Holt's linear model are based on the last four years of data. The data for FY97 and FY98 are not used in the computation of MAPE because these values were used to initialize the forecast. Holt's linear model works particularly well for the data set because costs trend upward every year.

Table 79 displays the actual, budgeted, and forecasted SH-60F CPFH figures. Percentage deviations from actual data are given. The actual values versus budgeted values percent error is worse than SES and Holt's linear model. The budgeted figures are better than the MA3 model. SES and Holt's linear model perform substantially better than the budgeted figures. Therefore, the SES model and Holt's linear model would have predicted a figure closer to the actual numbers. Holt's linear model forecasts values extremely close to the actual dollar amounts for this helicopter.

Table 79. SH-60F Actual, Budgeted, Forecast Comparison

FY00	Budgeted	Actual	MA3 Forecast	SES Forecast	Holt's LM Forecast
	$ 1,742.50	**$ 2,414.65**	**$ 1,711.31**	**$ 1,896.96**	**$ 2,276.33**
Actuals vs. Budgeted	27.84%				
Actuals vs. Forecast			29.13%	21.44%	5.73%
FY01	**Budgeted**	**Actual**	**3YMA Forecast**	**SES Forecast**	**Holt's LM Forecast**
	$ 2,191.41	**$ 2,632.21**	**$ 2,020.56**	**$ 2,414.65**	**$ 2,539.47**
Actuals vs. Budgeted	16.75%				
Actuals vs. Forecast			23.24%	8.27%	3.52%
FY02	**Budgeted**	**Actual**	**3YMA Forecast**	**SES Forecast**	**Holt's LM Forecast**
	$ 2,566.34	**$ 2,775.63**	**$ 2,314.61**	**$ 2,632.21**	**$ 2,802.61**
Actuals vs. Budgeted	7.54%				
Actuals vs. Forecast			16.61%	5.17%	-0.97%

UH-1N Helicopter Results

UH-1N CES Trends.

The results and analysis for the UH-1N helicopter follows next. Tables 80 through 85 show FY97-FY02 costs associated with the UH-1N helicopter. All costs reported in Tables 80 through 85 are reported in CY FY04 dollars. The data shows O&S costs by Major Claimant, total O&S cost, number of flying hours flown, and overall O&S CPFH.

Table 80. 1997 UH-1N Costs

CES	CINCLANTFLT	CINCPACFLT	CHNAVRES
1.0 Mission Personnel	$ 1,570,224	$ 27,491,836	$ 2,422,518
2.0 Unit-Level Consumption	$ 6,378,179	$ 12,255,810	$ 2,624,818
3.0 Intermediate Maintenance	$ 7,202,250	$ 15,494,598	$ 1,902,952
4.0 Depot Maintenance	$ 6,313,939	$ 9,423,040	$ 4,158,543
5.0 Contractor Support	$ 123,771	$ 252,923	$ 103,322
6.0 Sustaining Support	$ 7,420,809	$ 15,150,378	$ 5,538,033
7.0 Indirect Support			
Total Cost	$ 29,009,172	$ 80,068,585	$ 16,750,186
# of Aircraft	25	58	20
# Flying Hours	4,032	12,613	3,197
O&S CPFH	$ 7,194.74	$ 6,348.10	$ 5,239.35

Total Overall UH-1N O&S Cost
$125,827,943

Total Overall UH-1N # of Flying Hours
19,842

Total Overall UH-1N O&S CPFH
$6,341.49

Table 81. 1998 UH-1N Costs

CES	CINCLANTFLT	CINCPACFLT	CHNAVRES
1.0 Mission Personnel	$ 11,539,850	$ 26,712,231	$ 629,677
2.0 Unit-Level Consumption	$ 10,575,740	$ 18,441,219	$ 2,864,799
3.0 Intermediate Maintenance	$ 5,621,683	$ 14,944,991	$ 1,765,168
4.0 Depot Maintenance	$ 4,208,906	$ 9,490,104	$ 1,396,708
5.0 Contractor Support	$ 134,380	$ 295,422	$ 107,717
6.0 Sustaining Support	$ 5,953,083	$ 13,692,725	$ 5,051,945
7.0 Indirect Support			
Total Cost	$ 38,033,642	$ 83,576,692	$ 11,816,014
# of Aircraft	23	54	20
# Flying Hours	4301	12532	3189
O&S CPFH	$ 8,842.98	$ 6,669.06	$ 3,705.24

Total Overall UH-1N O&S Cost
$133,426,348

Total Overall UH-1N # of Flying Hours
20,022

Total Overall UH-1N O&S CPFH
$6,663.99

Table 82. 1999 UH-1N Costs

CES	CINCLANTFLT	CINCPACFLT	CHNAVRES
1.0 Mission Personnel	$ 13,827,663	$ 24,730,279	$ 2,555,286
2.0 Unit-Level Consumption	$ 14,190,662	$ 19,065,341	$ 3,440,656
3.0 Intermediate Maintenance	$ 5,643,563	$ 8,652,455	$ 1,464,499
4.0 Depot Maintenance	$ 2,030,491	$ 8,957,928	$ 5,669,974
5.0 Contractor Support	$ 129,948	$ 298,985	$ 113,044
6.0 Sustaining Support	$ 8,926,311	$ 20,818,904	$ 7,333,720
7.0 Indirect Support			
Total Cost	$ 44,748,638	$ 82,523,892	$ 20,577,179
# of Aircraft	23	54	19
# Flying Hours	5600	12595	3178
O&S CPFH	$ 7,990.83	$ 6,552.12	$ 6,474.88

Total Overall UH-1N O&S Cost
$147,849,709

Total Overall UH-1N # of Flying Hours
21,373

Total Overall UH-1N O&S CPFH
$6,917.59

Table 83. 2000 UH-1N Costs

CES	CINCLANTFLT	CINCPACFLT	CHNAVRES
1.0 Mission Personnel	$ 14,015,053	$ 27,725,900	$ 1,929,747
2.0 Unit-Level Consumption	$ 12,291,078	$ 23,756,584	$ 4,028,975
3.0 Intermediate Maintenance	$ 6,559,471	$ 8,524,317	$ 1,249,665
4.0 Depot Maintenance	$ 3,927,104	$ 7,096,611	$ 1,403,863
5.0 Contractor Support	$ 216,190	$ 482,245	$ 107,300
6.0 Sustaining Support	$ 7,894,001	$ 18,471,063	$ 6,912,076
7.0 Indirect Support			
Total Cost	$ 44,902,897	$ 86,056,720	$ 15,631,626
# of Aircraft	23	54	20
# Flying Hours	5126	10891	3127
O&S CPFH	$ 8,759.83	$ 7,901.64	$ 4,998.92

Total Overall UH-1N O&S Cost
$146,591,243

Total Overall UH-1N # of Flying Hours
19,144

Total Overall UH-1N O&S CPFH
$7,657.29

Table 84. 2001 UH-1N Costs

CES	CINCLANTFLT	CINCPACFLT	CHNAVRES
1.0 Mission Personnel	$ 15,254,023	$ 28,883,972	$ 1,807,981
2.0 Unit-Level Consumption	$ 9,296,967	$ 25,914,814	$ 3,367,340
3.0 Intermediate Maintenance	$ 6,437,377	$ 12,740,956	$ 1,245,422
4.0 Depot Maintenance	$ 3,785,560	$ 2,530,661	$ 801,995
5.0 Contractor Support	$ 275,358	$ 455,173	$ 116,745
6.0 Sustaining Support	$ 6,207,061	$ 14,303,227	$ 5,397,446
7.0 Indirect Support	$ 396,542	$ 703,986	$ 15,897
Total Cost	$ 41,652,888	$ 85,532,789	$ 12,752,826
# of Aircraft	23	53	20
# Flying Hours	5002	11974	3038
O&S CPFH	$ 8,327.25	$ 7,143.21	$ 4,197.77
Total Overall UH-1N O&S Cost			
$139,938,503			
Total Overall UH-1N # of Flying Hours			
20,014			
Total Overall UH-1N O&S CPFH			
$6,992.03			

Table 85. 2002 UH-1N Costs

CES	CINCLANTFLT	CINCPACFLT	CHNAVRES
1.0 Mission Personnel	$ 13,108,603	$ 27,266,116	$ 1,727,640
2.0 Unit-Level Consumption	$ 10,645,485	$ 25,405,755	$ 4,744,217
3.0 Intermediate Maintenance	$ 5,817,838	$ 11,756,782	$ 1,041,957
4.0 Depot Maintenance	$ 2,717,424	$ 2,375,284	$ 1,370,649
5.0 Contractor Support	$ 216,900	$ 644,512	$ 124,428
6.0 Sustaining Support	$ 7,061,974	$ 15,775,739	$ 6,353,236
7.0 Indirect Support	$ 280,144	$ 550,250	$ 142,600
Total Cost	$ 39,848,368	$ 83,774,438	$ 15,504,727
# of Aircraft	22	49	20
# Flying Hours	4762	11573	3330
O&S CPFH	$ 8,367.99	$ 7,238.78	$ 4,656.07
Total Overall UH-1N O&S Cost			
$139,127,533			
Total Overall UH-1N # of Flying Hours			
19,665			
Total Overall UH-1N O&S CPFH			
$7,074.88			

The total overall O&S CPFH represents the total O&S costs associated with the helicopter for that particular year divided by the number of flying hours. This number gives a good indication if costs are increasing or decreasing. The CPFH for the UH-1N steadily increases over time. CPFH increases substantially during FY00 but subsequently decreases, and begins to rise again. Because the numbers are in CY FY04 dollars, the effects of inflation are negated. Therefore, the numbers give a true indication of whether or not costs for the weapon system are escalating.

The components of the UH-1N CES are analyzed and computed as a percent of total O&S cost. The percentages are tallied by year and by Major Claimant. Table 86 shows the results of the O&S CES components as percentages of total O&S costs. The Major Claimant results are not shown individually. Instead, Table 86 shows the results of the Major Claimants collectively.

Table 86. UH-1N CES Elements as a Percentage of Total O&S Cost

CES	1997	1998	1999	2000	2001	2002
1.0 Mission Personnel	25.02%	29.14%	27.81%	29.79%	32.83%	30.26%
2.0 Unit-Level Consumption	16.90%	23.89%	24.82%	27.34%	27.57%	29.32%
3.0 Intermediate Maintenance	19.55%	16.74%	10.66%	11.14%	14.59%	13.38%
4.0 Depot Maintenance	15.81%	11.31%	11.27%	8.48%	5.09%	4.65%
5.0 Contractor Support	0.38%	0.40%	0.37%	0.55%	0.61%	0.71%
6.0 Sustaining Support	22.34%	18.51%	25.08%	22.70%	18.51%	20.98%
7.0 Indirect Support	0.00%	0.00%	0.00%	0.00%	0.80%	0.70%

In addition to the table above, a line chart is created to show the CES elements over time. The line chart makes it easier to examine any existing trends. Figure 46 depicts the cost data as a percentage of the total cost. The costs are sorted by the seven CES components in Tables 80 through 85. The costs represent all Major Claimants. Collectively, the CES components rise over time. Mission Personnel and Unit-Level Consumption notably increase during the period studied. The former increases approximately five percent while the latter CES component increases over 12 percent. The large increase in Unit-Level Consumption suggests an increase in CPFH during FY97-FY02.

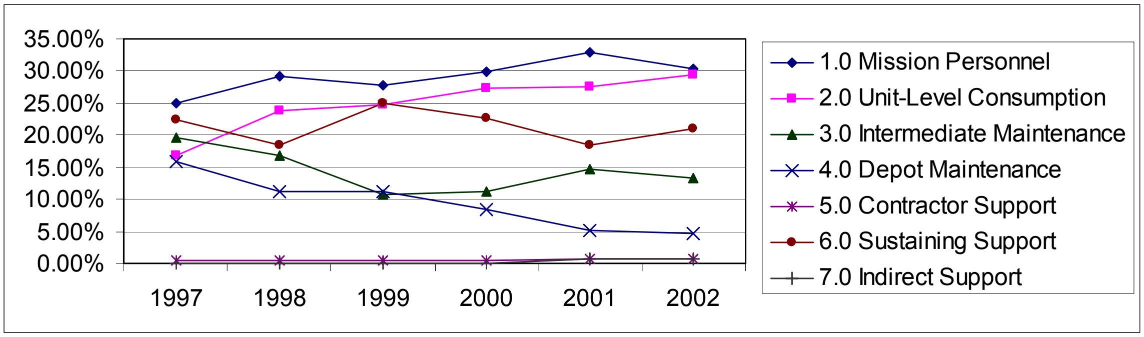

Figure 46. UH-1N CES Trends

UH-1N CPFH Trends.

A closer look at the individual components of CES 2.0 is necessary to determine the primary cost drivers for CPFH. Tables 87 through 92 illustrate the CPFH break-out for the UH-1N helicopter. Additionally, Figures 47 through 52 show the CPFH percentage composition. Major increases or decreases to the CPFH components suggest cost drivers in developing trends.

Table 87. 1997 UH-1N CPFH

CES	CINCLANTFLT	CINCPACFLT	CHNAVRES
2.1 POL/Energy Consumables	$ 353,624	$ 869,084	$ 242,588
2.2 Consumable Materials/Repair Parts	$ 3,858,462	$ 6,758,169	$ 1,425,638
2.3 Depot Level Reparables	$ 1,511,186	$ 3,250,032	$ 689,018
Total Cost	$ 5,723,272	$ 10,877,285	$ 2,357,244
CPFH by Command	$ 1,419	$ 862	$ 737
Total Overall UH-1N Flying Hour Costs			
$18,957,801			
Total Overall UH-1N CPFH			
$955.44			

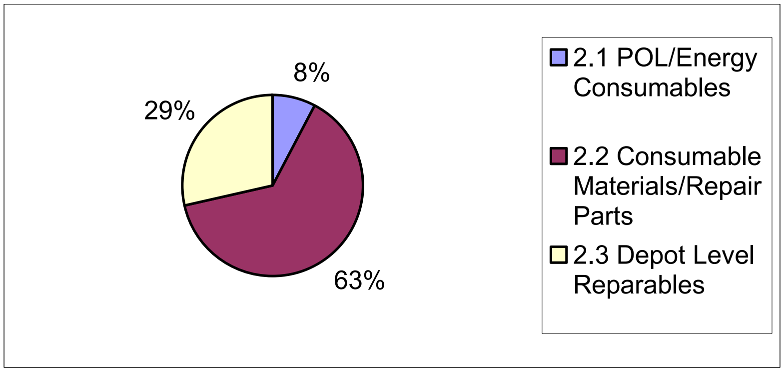

Figure 47. 1997 UH-1N CPFH Percentage Composition

Table 88. 1998 UH-1N CPFH

CES	CINCLANTFLT	CINCPACFLT	CHNAVRES
2.1 POL/Energy Consumables	$ 488,034	$ 1,044,088	$ 251,421
2.2 Consumable Materials/Repair Parts	$ 4,295,409	$ 8,254,606	$ 1,308,893
2.3 Depot Level Reparables	$ 4,808,572	$ 7,475,427	$ 1,003,581
Total Cost	$ 9,592,015	$ 16,774,121	$ 2,563,895
CPFH by Command	$ 2,230	$ 1,339	$ 804
Total Overall UH-1N Flying Hour Costs			
$28,930,031			
Total Overall UH-1N CPFH			
$1,444.91			

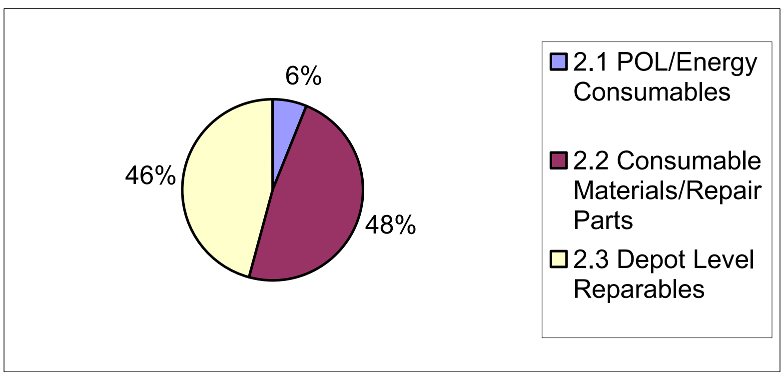

Figure 48. 1998 UH-1N CPFH Percentage Composition

Table 89. 1999 UH-1N CPFH

CES	CINCLANTFLT	CINCPACFLT	CHNAVRES
2.1 POL/Energy Consumables	$ 499,520	$ 989,072	$ 276,200
2.2 Consumable Materials/Repair Parts	$ 5,668,712	$ 9,854,202	$ 1,793,377
2.3 Depot Level Reparables	$ 6,799,192	$ 6,756,562	$ 1,017,784
Total Cost	$ 12,967,424	$ 17,599,836	$ 3,087,361
CPFH by Command	$ 2,316	$ 1,397	$ 971
Total Overall UH-1N Flying Hour Costs			
$33,654,621			
Total Overall UH-1N CPFH			
$1,574.63			

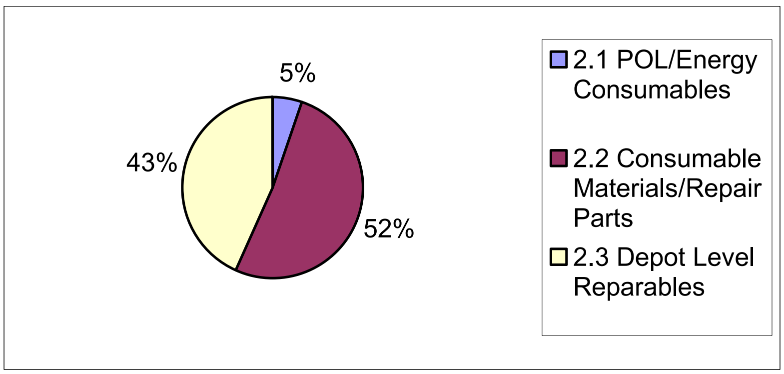

Figure 49. 1999 UH-1N CPFH Percentage Composition

Table 90. 2000 UH-1N CPFH

CES	CINCLANTFLT	CINCPACFLT	CHNAVRES
2.1 POL/Energy Consumables	$ 420,588	$ 739,895	$ 205,100
2.2 Consumable Materials/Repair Parts	$ 5,045,522	$ 11,082,086	$ 1,676,729
2.3 Depot Level Reparables	$ 5,002,979	$ 8,091,619	$ 1,056,703
Total Cost	$ 10,469,089	$ 19,913,600	$ 2,938,532
CPFH by Command	$ 2,042	$ 1,828	$ 940
Total Overall UH-1N Flying Hour Costs			
$33,321,221			
Total Overall UH-1N CPFH			
$1,740.56			

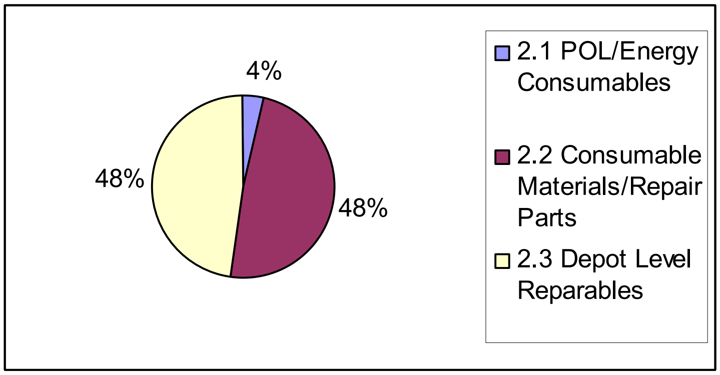

Figure 50. 2000 UH-1N CPFH Percentage Composition

Table 91. 2001 UH-1N CPFH

CES	CINCLANTFLT	CINCPACFLT	CHNAVRES
2.1 POL/Energy Consumables	$ 526,661	$ 1,365,056	$ 314,433
2.2 Consumable Materials/Repair Parts	$ 4,961,184	$ 13,150,031	$ 1,469,724
2.3 Depot Level Reparables	$ 3,480,692	$ 10,465,527	$ 1,480,296
Total Cost	$ 8,968,537	$ 24,980,614	$ 3,264,453
CPFH by Command	$ 1,793	$ 2,086	$ 1,075
Total Overall UH-1N Flying Hour Costs			
$37,213,604			
Total Overall UH-1N CPFH			
$1,859.38			

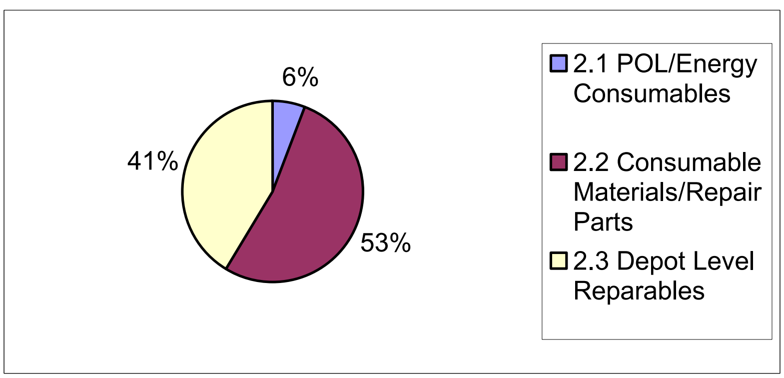

Figure 51. 2001 UH-1N CPFH Percentage Composition

Table 92. 2002 UH-1N CPFH

CES	CINCLANTFLT	CINCPACFLT	CHNAVRES
2.1 POL/Energy Consumables	$ 476,243	$ 1,209,608	$ 321,412
2.2 Consumable Materials/Repair Parts	$ 5,733,133	$ 12,828,482	$ 2,116,881
2.3 Depot Level Reparables	$ 4,218,994	$ 10,846,297	$ 2,210,598
Total Cost	$ 10,428,370	$ 24,884,387	$ 4,648,891
CPFH by Command	$ 2,190	$ 2,150	$ 1,396
Total Overall UH-1N Flying Hour Costs			
$39,961,648			
Total Overall UH-1N CPFH			
$2,032.12			

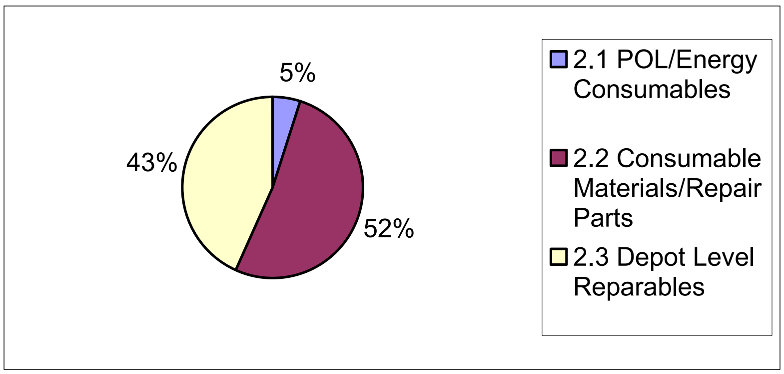

Figure 52. 2002 UH-1N CPFH Percentage Composition

The CPFH components for the UH-1N helicopter change over the course of time. The main cost drivers are DLRs and consumable materials/repair parts. Fuel cost as a percentage of the CES is stable. The percentage make-up is drastically different in FY97 when compared to other years. Consumable materials/repair parts make up the largest percentage of the CES. CPFH costs trend upward. In fact, CPFH increases every year during the period studied.

UH-1N Forecasting Results.

Cost data in Tables 93 through 95 is used to develop models for predicting future costs. Three forecasting techniques, as described in Chapter III, are utilized to build the three models. Table 93 shows the results from using the MA3 method with historical

CPFH data. Table 94 displays the results from the SES method. Table 95 calculates Holt's linear method.

Table 93. UH-1N MA3 CPFH Calculation

	Yt	Ft	Error	|Error|	(Error/Yt)*100	|(Error/Yt)|*100
Fiscal Year	CPFH	MA3	Yt-Ft	|Yt-Ft|	Percent Error	Absolute Percent Error
1997	$955					
1998	$1,445					
1999	$1,575					
2000	$1,741	$1,325	$416	$416	23.88%	23.88%
2001	$1,859	$1,587	$273	$273	14.67%	14.67%
2002	$2,032	$1,725	$307	$307	15.12%	15.12%
2003		$1,877				
Total			$996	$996	53.66%	53.66%
			ME	MAE	MPE	MAPE
			$332	$332	17.89%	17.89%

Table 94. UH-1N SES CPFH Calculation

α = 1

Ft	Error	|Error|	(Error/Yt)*100	|(Error/Yt)|*100
SES	Yt-Ft	|Yt-Ft|	Percent Error	Absolute Percent Error
$955	$489	$489	33.88%	33.88%
$1,445	$130	$130	8.24%	8.24%
$1,575	$166	$166	9.53%	9.53%
$1,741	$119	$119	6.39%	6.39%
$1,859	$173	$173	8.50%	8.50%
$2,032				
	$587	$587	32.66%	32.66%
	ME	MAE	MPE	MAPE
	$147	$147	8.17%	8.17%

Table 95. UH-1N Holt's Linear Method CPFH Calculation

		α =	0.949681755	β =	1	m =	1
		Ft	Error	|Error|	(Error/Yt)*100		|(Error/Yt)|*100
L_t	b_t	Holt's LM	Yt-Ft	|Yt-Ft|	Percent Error		Absolute Percent Error
$955	$489						
$1,445	$489	$1,445	$0	$0	0.00%		0.00%
$1,593	$148	$1,934	-$360	$360	-22.85%		22.85%
$1,741	$148	$1,741	$0	$0	0.00%		0.00%
$1,861	$120	$1,888	-$29	$29	-1.56%		1.56%
$2,030	$169	$1,981	$51	$51	2.51%		2.51%
		$2,198					
			-$338	$440	-21.90%		26.92%
			ME	MAE	MPE		MAPE
			-$84	$110	-5.47%		6.73%

The best forecasting model for the UH-1N helicopter, with respect to MAPE, is Holt's linear model in Table 95. With a MAPE of 6.73%, Holt's linear method out-performs MA3 and SES. Additionally, all of the summary statistics are better for the Holt's linear method model when compared with the other models. The summary statistics for the SES model and Holt's linear model are based on the last four years of data. FY97 and FY98 data are not used in the computation of MAPE because the data for these years are used to initialize the forecast. Holt's linear method works particularly well for the data set because the costs trend upward every year.

Table 96 displays the actual, budgeted, and forecasted UH-1N CPFH figures in an easy to read format. Percentage deviations from actual data are given. The actual values versus budgeted values percent error is worse than SES and Holt's linear method. The budgeted figures are better than the MA3 model. SES and Holt's linear method perform substantially better than the budgeted figures. Therefore, the SES model and Holt's linear model would have predicted a figure closer to the actual numbers. Holt's linear method comes very close to the actual dollar amounts for this helicopter every year.

Table 96. UH-1N Actual, Budgeted, Forecast Comparison

FY00	Budgeted	Actual	MA3 Forecast	SES Forecast	Holt's LM Forecast
	$ 1,190.91	$ 1,740.56	$ 1,324.99	$ 1,574.63	$ 1,740.56
Actuals vs. Budgeted	31.58%				
Actuals vs. Forecast			23.88%	9.53%	0.00%
FY01	**Budgeted**	**Actual**	**3YMA Forecast**	**SES Forecast**	**Holt's LM Forecast**
	$ 1,732.60	$ 1,859.38	$ 1,586.70	$ 1,740.56	$ 1,888.38
Actuals vs. Budgeted	6.82%				
Actuals vs. Forecast			14.67%	6.39%	-1.56%
FY02	**Budgeted**	**Actual**	**3YMA Forecast**	**SES Forecast**	**Holt's LM Forecast**
	$ 1,992.01	$ 2,032.12	$ 1,724.86	$ 1,859.38	$ 1,981.12
Actuals vs. Budgeted	1.97%				
Actuals vs. Forecast			15.12%	8.50%	2.51%

UH-3H Helicopter Results

UH-3H CES Trends.

The results and analysis for the UH-3H helicopter are described in the following section. Tables 97 through 102 show FY97-FY02 costs associated with the UH-3H helicopter. All costs reported in Tables 97 through 102 are reported in CY FY04 dollars. The data shows O&S costs by Major Claimant, total O&S cost, number of flying hours flown, and overall O&S CPFH.

Table 97. 1997 UH-3H Costs

CES	CINCLANTFLT	CINCPACFLT	CHNAVRES	CNET
1.0 Mission Personnel	$ 22,761,729	$ 9,956,576	$ 7,789,801	$ 2,286,246
2.0 Unit-Level Consumption	$ 17,907,768	$ 5,420,380	$ 4,002,614	$ 1,233,385
3.0 Intermediate Maintenance	$ 2,721,053	$ 1,125,742		$ 80,724
4.0 Depot Maintenance	$ 3,585,013	$ 497,493	$ 209,215	$ 86,637
5.0 Contractor Support	$ 91,483	$ 22,602		$ 11,839
6.0 Sustaining Support	$ 4,375,471	$ 1,094,184		$ 546,987
7.0 Indirect Support				
Total Cost	$ 51,442,517	$ 18,116,977	$ 12,001,630	$ 4,245,818
# of Aircraft	25	11	10	3
# Flying Hours	7,796	2,720	2,774	903
O&S CPFH	$ 6,598.58	$ 6,660.65	$ 4,326.47	$ 4,701.90

Total Overall UH-3H O&S Cost
$85,806,942

Total Overall UH-3H # of Flying Hours
14,193

Total Overall UH-3H O&S CPFH
$6,045.72

Table 98. 1998 UH-3H Costs

CES	CINCLANTFLT	CINCPACFLT	CHNAVRES	CNET
1.0 Mission Personnel	$ 24,273,988	$ 3,380,065	$ 8,752,900	$ 1,980,675
2.0 Unit-Level Consumption	$ 22,407,345	$ 4,515,251	$ 5,047,530	$ 1,424,093
3.0 Intermediate Maintenance	$ 2,357,576	$ 1,190,464	$ 125,524	$ 406,436
4.0 Depot Maintenance	$ 2,462,700	$ 94,371	$ 551,316	$ 168,073
5.0 Contractor Support	$ 113,050	$ 28,796	$ 46,926	$ 13,865
6.0 Sustaining Support	$ 3,657,220	$ 936,125	$ 1,470,373	$ 447,317
7.0 Indirect Support				
Total Cost	$ 55,271,879	$ 10,145,072	$ 15,994,569	$ 4,440,459
# of Aircraft	25	5	10	3
# Flying Hours	8,599	3,016	2,801	764
O&S CPFH	$ 6,427.71	$ 3,363.75	$ 5,710.31	$ 5,812.12

Total Overall UH-3H O&S Cost
$85,851,979

Total Overall UH-3H # of Flying Hours
15,180

Total Overall UH-3H O&S CPFH
$5,655.60

Table 99. 1999 UH-3H Costs

CES	CINCLANTFLT	CINCPACFLT	CHNAVRES	CNET
1.0 Mission Personnel	$ 22,913,822	$ 7,089,234	$ 8,217,549	$ 461,255
2.0 Unit-Level Consumption	$ 16,695,563	$ 9,149,424	$ 5,995,632	$ 2,096,799
3.0 Intermediate Maintenance	$ 1,876,148	$ 1,057,075	$ 73,973	$ 43,615
4.0 Depot Maintenance	$ 2,564,534	$ 279,420	$ 620,180	$ 41,150
5.0 Contractor Support	$ 146,851	$ 38,033	$ 57,050	$ 679,813
6.0 Sustaining Support	$ 3,901,052	$ 1,454,310	$ 1,450,541	$ 488,105
7.0 Indirect Support				
Total Cost	$ 48,097,970	$ 19,067,496	$ 16,414,925	$ 3,810,737
# of Aircraft	25	11	9	$ 3
# Flying Hours	7,546	3,859	2,315	739
O&S CPFH	$ 6,373.97	$ 4,941.05	$ 7,090.68	$ 5,156.61

Total Overall UH-3H O&S Cost
$87,391,128

Total Overall UH-3H # of Flying Hours
14,459

Total Overall UH-3H O&S CPFH
$6,044.06

Table 100. 2000 UH-3H Costs

CES	CINCLANTFLT	CINCPACFLT	CHNAVRES	CNET
1.0 Mission Personnel	$ 24,866,177	$ 8,081,132	$ 7,090,006	$ 364,188
2.0 Unit-Level Consumption	$ 22,469,100	$ 9,227,312	$ 3,513,666	$ 2,513,317
3.0 Intermediate Maintenance	$ 2,128,745	$ 1,100,679	$ 75,570	$ 33,767
4.0 Depot Maintenance	$ 7,383,012	$ 727,614	$ 1,851,838	$ 548,560
5.0 Contractor Support	$ 67,394	$ 28,127	$ 22,918	$ 918,492
6.0 Sustaining Support	$ 4,276,293	$ 2,034,335	$ 1,631,432	$ 531,336
7.0 Indirect Support				
Total Cost	$ 61,190,721	$ 21,199,199	$ 14,185,430	$ 4,909,660
# of Aircraft	23	11	9	3
# Flying Hours	7,041	3,141	2,214	966
O&S CPFH	$ 8,690.63	$ 6,749.19	$ 6,407.15	$ 5,082.46

Total Overall UH-3H O&S Cost
$101,485,010

Total Overall UH-3H # of Flying Hours
13,362

Total Overall UH-3H O&S CPFH
$7,595.05

Table 101. 2001 UH-3H Costs

CES	CINCLANTFLT	CINCPACFLT	CHNAVRES	CNET
1.0 Mission Personnel	$ 25,486,839	$ 8,187,627	$ 7,385,745	$ 359,473
2.0 Unit-Level Consumption	$ 19,992,360	$ 6,534,005	$ 3,997,817	$ 2,499,879
3.0 Intermediate Maintenance	$ 2,017,241	$ 1,280,748	$ 892	$ 42,902
4.0 Depot Maintenance	$ 6,467,496	$ 3,699,675	$ 3,856,613	$ 197,917
5.0 Contractor Support	$ 180,846	$ 31,912	$ 26,110	$ 843,555
6.0 Sustaining Support	$ 5,377,249	$ 2,300,947	$ 1,833,654	$ 608,882
7.0 Indirect Support	$ 292,412	$ 219,636	$ 95,321	$ 13,306
Total Cost	$ 59,814,443	$ 22,254,550	$ 17,196,152	$ 4,565,914
# of Aircraft	25	11	9	3
# Flying Hours	7,292	3,060	2,302	814
O&S CPFH	$ 8,202.75	$ 7,272.73	$ 7,470.09	$ 5,609.23

Total Overall UH-3H O&S Cost
$103,831,059

Total Overall UH-3H # of Flying Hours
13,468

Total Overall UH-3H O&S CPFH
$7,709.46

Table 102. 2002 UH-3H Costs

CES	CINCLANTFLT	CINCPACFLT	CHNAVRES	CNET
1.0 Mission Personnel	$ 26,519,276	$ 8,909,383	$ 7,531,532	$ 1,689,413
2.0 Unit-Level Consumption	$ 23,685,344	$ 8,730,897	$ 5,746,176	$ 1,244,588
3.0 Intermediate Maintenance	$ 2,356,165	$ 1,663,958		$ 171,491
4.0 Depot Maintenance	$ 9,872,820	$ 7,805,587	$ 2,657,590	$ 2,366,386
5.0 Contractor Support	$ 140,765	$ 33,606	$ 24,441	$ 1,027,814
6.0 Sustaining Support	$ 6,268,651	$ 2,457,096	$ 1,753,586	$ 645,046
7.0 Indirect Support	$ 292,233	$ 332,433	$ 81,768	$ 24,963
Total Cost	$ 69,135,254	$ 29,932,960	$ 17,795,093	$ 7,169,701
# of Aircraft	25	11	8	3
# Flying Hours	7,730	2,771	2,437	829
O&S CPFH	$ 8,943.76	$ 10,802.22	$ 7,302.05	$ 8,648.61

Total Overall UH-3H O&S Cost
$124,033,008

Total Overall UH-3H # of Flying Hours
13,767

Total Overall UH-3H O&S CPFH
$9,009.44

The overall O&S CPFH represents the total O&S costs associated with the helicopter for that particular year divided by the number of flying hours. This number gives a good indication if costs are increasing or decreasing. Overall costs, as well as CPFH, for the UH-3H steadily increase over time. The increase in CPFH and overall costs occurs even though flying hours per year decrease over time. The cost of maintainability over time or block upgrades to the aircraft may have caused the increase. Because the numbers are in CY FY04 dollars, the effects of inflation are negated. Therefore, the numbers give a true indication of whether or not weapon system costs are escalating.

The components of the UH-3H CES are analyzed and computed as a percent of total O&S cost. The percentages are tallied by year and by Major Claimant. Table 103 shows the results of the O&S CES components as percentages of total O&S costs. The Major Claimant results are not shown individually. Instead, Table 103 shows the results of the Major Claimants collectively.

Table 103. UH-3H CES Elements as a Percentage of Total O&S Cost

CES	1997	1998	1999	2000	2001	2002
1.0 Mission Personnel	49.87%	44.71%	44.26%	39.81%	39.89%	36.00%
2.0 Unit-Level Consumption	33.29%	38.90%	38.83%	37.17%	31.81%	31.77%
3.0 Intermediate Maintenance	4.58%	4.75%	3.49%	3.29%	3.22%	3.38%
4.0 Depot Maintenance	5.10%	3.82%	4.01%	10.36%	13.70%	18.30%
5.0 Contractor Support	0.15%	0.24%	1.05%	1.02%	1.04%	0.99%
6.0 Sustaining Support	7.01%	7.58%	8.35%	8.35%	9.75%	8.97%
7.0 Indirect Support	0.00%	0.00%	0.00%	0.00%	0.60%	0.59%

In addition to the table above, a line chart is created to show the CES components over time. The line chart allows an examination of existing trends. Figure 53 shows the cost data as a percentage of the total cost. The costs are sorted by the seven CES components in Tables 97 through 102. The costs represent all Major Claimants. Collectively, the CES components rise over time. Mission Personnel notably decreases during the period almost 14 percent. Depot Maintenance increases approximately 13 percent. The increase in Depot Maintenance suggests that the rising cost could possibly be attributed to block upgrades.

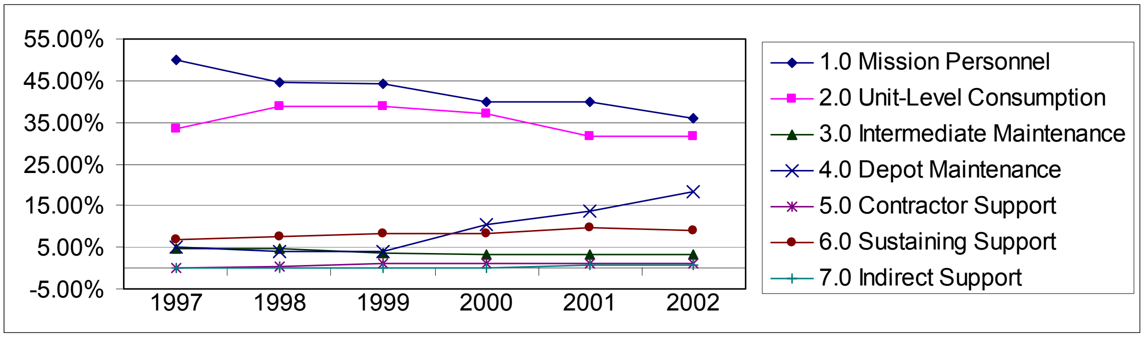

Figure 53. UH-3H CES Trends

UH-3H CPFH Trends.

A closer look at the individual components of CES 2.0 is necessary to determine the primary cost drivers are for CPFH. Tables 104 through 109 illustrate the CPFH break-out for the UH-3H helicopter. Additionally, Figures 54 through 59 show the CPFH percentage composition. Major increases or decreases to the CPFH components suggest cost drivers in developing trends.

Table 104. 1997 UH-3H CPFH

CES	CINCLANTFLT	CINCPACFLT	CHNAVRES	CNET
2.1 POL/Energy Consumables	$ 947,034	$ 333,647	$ 312,373	$ 107,728
2.2 Consumable Materials/Repair Parts	$ 2,615,785	$ 870,003	$ 774,035	$ 293,737
2.3 Depot Level Reparables	$ 9,305,208	$ 2,704,237	$ 2,401,939	$ 466,354
Total Cost	$ 12,868,027	$ 3,907,887	$ 3,488,347	$ 867,819
CPFH by Command	$ 1,651	$ 1,437	$ 1,258	$ 961

Total Overall UH-3H Flying Hour Costs
$21,132,080

Total Overall UH-3H CPFH
$1,488.91

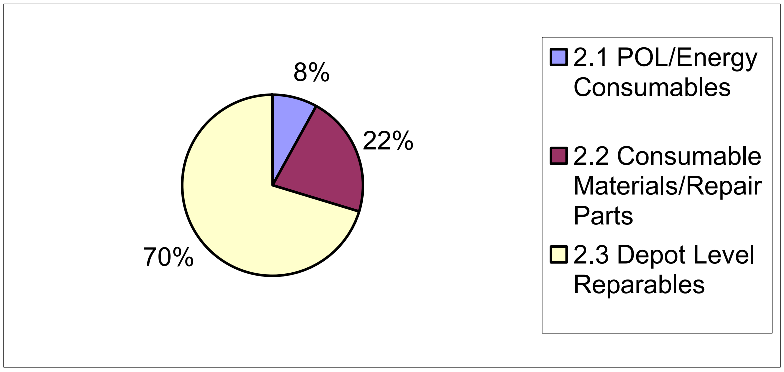

Figure 54. 1997 UH-3H CPFH Percentage Composition

Table 105. 1998 UH-3H CPFH

CES	CINCLANTFLT	CINCPACFLT	CHNAVRES	CNET
2.1 POL/Energy Consumables	$ 1,128,779	$ 410,682	$ 364,382	$ 100,611
2.2 Consumable Materials/Repair Parts	$ 3,061,127	$ 814,070	$ 982,745	$ 273,565
2.3 Depot Level Reparables	$ 15,750,580	$ 1,997,502	$ 3,179,538	$ 724,417
Total Cost	$ 19,940,486	$ 3,222,254	$ 4,526,665	$ 1,098,593
CPFH by Command	$ 2,319	$ 1,068	$ 1,616	$ 1,438
Total Overall UH-3H Flying Hour Costs				
$28,787,998				
Total Overall UH-3H CPFH				
$1,896.44				

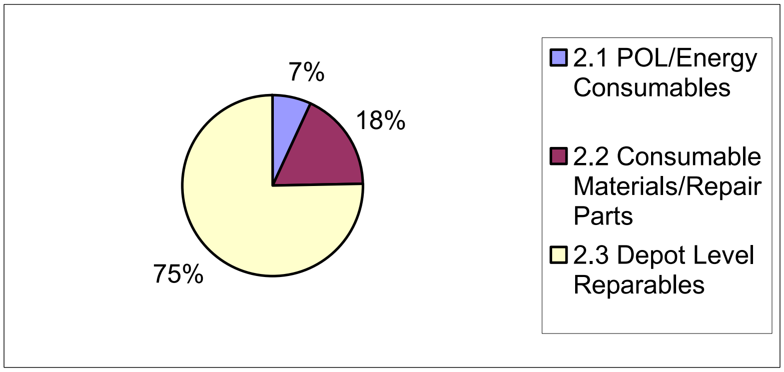

Figure 55. 1998 UH-3H CPFH Percentage Composition

Table 106. 1999 UH-3H CPFH

CES	CINCLANTFLT	CINCPACFLT	CHNAVRES	CNET
2.1 POL/Energy Consumables	$ 998,021	$ 364,078	$ 289,477	$ 87,305
2.2 Consumable Materials/Repair Parts	$ 2,265,159	$ 1,216,170	$ 970,967	$ 568,890
2.3 Depot Level Reparables	$ 11,791,535	$ 5,713,453	$ 4,152,680	$ 1,249,664
Total Cost	$ 15,054,715	$ 7,293,701	$ 5,413,124	$ 1,905,859
CPFH by Command	$ 1,995	$ 1,890	$ 2,338	$ 2,579

Total Overall UH-3H Flying Hour Costs
$29,667,399

Total Overall UH-3H CPFH
$2,051.83

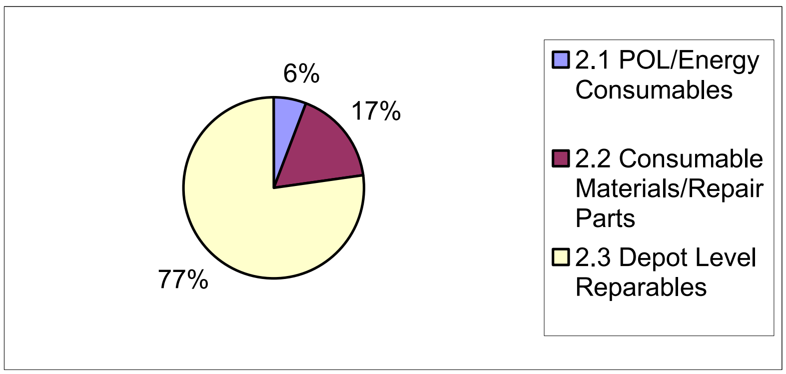

Figure 56. 1999 UH-3H CPFH Percentage Composition

Table 107. 2000 UH-3H CPFH

CES	CINCLANTFLT	CINCPACFLT	CHNAVRES	CNET
2.1 POL/Energy Consumables	$ 690,656	$ 289,556	$ 198,684	$ 91,577
2.2 Consumable Materials/Repair Parts	$ 3,125,919	$ 892,545	$ 920,515	$ 289,162
2.3 Depot Level Reparables	$ 16,633,912	$ 5,831,597	$ 2,076,222	$ 1,905,561
Total Cost	$ 20,450,487	$ 7,013,698	$ 3,195,421	$ 2,286,300
CPFH by Command	$ 2,904	$ 2,233	$ 1,443	$ 2,367

Total Overall UH-3H Flying Hour Costs
$32,945,906

Total Overall UH-3H CPFH
$2,465.64

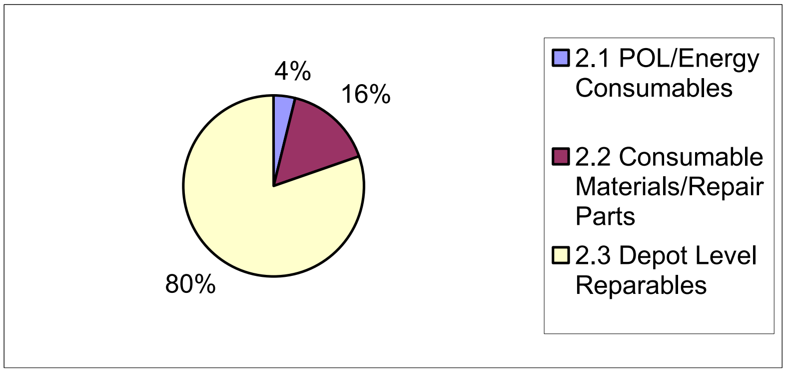

Figure 57. 2000 UH-3H CPFH Percentage Composition

Table 108. 2001 UH-3H CPFH

CES	CINCLANTFLT	CINCPACFLT	CHNAVRES	CNET
2.1 POL/Energy Consumables	$ 1,130,336	$ 453,056	$ 323,523	$ 137,997
2.2 Consumable Materials/Repair Parts	$ 3,050,849	$ 1,396,006	$ 941,748	$ 320,610
2.3 Depot Level Reparables	$ 14,893,784	$ 4,374,764	$ 2,573,807	$ 1,923,930
Total Cost	$ 19,074,969	$ 6,223,826	$ 3,839,078	$ 2,382,537
CPFH by Command	$ 2,616	$ 2,034	$ 1,668	$ 2,927

Total Overall UH-3H Flying Hour Costs
$31,520,410

Total Overall UH-3H CPFH
$2,340.39

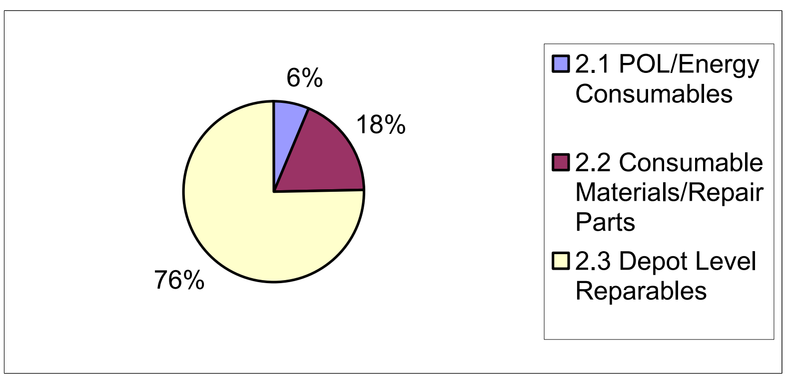

Figure 58. 2001 UH-3H CPFH Percentage Composition

Table 109. 2002 UH-3H CPFH

CES	CINCLANTFLT	CINCPACFLT	CHNAVRES	CNET
2.1 POL/Energy Consumables	$ 1,197,151	$ 413,844	$ 337,110	$ 128,321
2.2 Consumable Materials/Repair Parts	$ 4,315,427	$ 930,412	$ 987,984	$ 216,104
2.3 Depot Level Reparables	$ 17,595,582	$ 7,160,316	$ 4,285,619	$ 877,357
Total Cost	$ 23,108,160	$ 8,504,572	$ 5,610,713	$ 1,221,782
CPFH by Command	$ 2,989	$ 3,069	$ 2,302	$ 1,474
Total Overall UH-3H Flying Hour Costs				
$38,445,227				
Total Overall UH-3H CPFH				
$2,792.56				

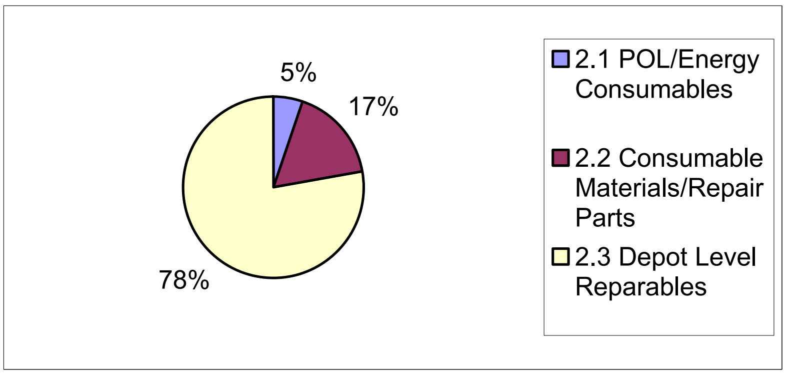

Figure 59. 2002 UH-3H CPFH Percentage Composition

The CPFH components for the UH-3H helicopter change over the course of time. The main cost driver is DLRs. Fuel cost as a percentage of the CES is stable. DLRs as a percentage of CPFH increase over time. Consumable Materials/Repair Parts decrease over time. Fuel costs stay relatively stable as a percentage of CPFH. CPFH costs trend upward almost every year.

UH-3H Forecasting Results.

Cost data in Tables 110 through 112 is used to develop models for predicting future costs. Three forecasting techniques, as described in Chapter III, are utilized to build the three models. Table 110 shows the results from using the MA3 method with historical CPFH data. Table 111 displays the results from the SES method. Table 112 illustrates Holt's linear method.

Table 110. UH-3H MA3 CPFH Calculation

	Yt	Ft	Error	|Error|	(Error/Yt)*100	|(Error/Yt)|*100
Fiscal Year	CPFH	MA3	Yt-Ft	|Yt-Ft|	Percent Error	Absolute Percent Error
1997	$1,489					
1998	$1,896					
1999	$2,052					
2000	$2,466	$1,812	$653	$653	26.49%	26.49%
2001	$2,340	$2,138	$202	$202	8.65%	8.65%
2002	$2,793	$2,286	$507	$507	18.14%	18.14%
2003		$2,533				
Total			$1,362	$1,362	53.28%	53.28%
			ME	MAE	MPE	MAPE
			$454	$454	17.76%	17.76%

Table 111. UH-3H SES CPFH Calculation

α = 1

Ft	Error	|Error|	(Error/Yt)*100	|(Error/Yt)|*100
SES	Yt-Ft	|Yt-Ft|	Percent Error	Absolute Percent Error
$1,489	$408	$408	21.49%	21.49%
$1,896	$155	$155	7.57%	7.57%
$2,052	$414	$414	16.78%	16.78%
$2,466	-$125	$125	-5.35%	5.35%
$2,340	$452	$452	16.19%	16.19%
$2,793				
	$896	$1,147	35.20%	45.90%
	ME	MAE	MPE	MAPE
	$224	$287	8.80%	11.47%

Table 112. UH-3H Holt's Linear Method CPFH Calculation

		α =	0.45109467	β =	0.610711443	m =	1
		Ft	Error	|Error|	(Error/Yt)*100		|(Error/Yt)|*100
L_t	b_t	Holt's LM	Yt-Ft	|Yt-Ft|	Percent Error		Absolute Percent Error
$1,489	$408						
$1,896	$408	$1,896	$0	$0	0.00%		0.00%
$2,190	$338	$2,304	-$252	$252	-12.29%		12.29%
$2,500	$321	$2,528	-$63	$63	-2.54%		2.54%
$2,604	$188	$2,821	-$480	$480	-20.53%		20.53%
$2,793	$188	$2,793	$0	$0	0.00%		0.00%
		$2,981					
			-$795	$795	-35.36%		35.36%
			ME	MAE	MPE		MAPE
			-$199	$199	-8.84%		8.84%

The best forecasting model for the UH-3H helicopter, based on minimizing MAPE, is Holt's linear method in Table 112. With a MAPE of 8.84%, Holt's linear method out-performs MA3 and SES. Additionally, the majority of the summary statistics are better for the Holt's linear method model when compared with the other models. The summary statistics for the SES model and Holt's linear model are based off of the last four years of data. FY97 and FY98 data are not used in the computation of MAPE because the data for these years initialize the forecast. Holt's linear method works particularly well for the data set because the costs trend upward almost every year.

Table 113 displays the actual, budgeted, and forecasted UH-3H CPFH figures in an easy to read format. Percentage deviations from the actual data are given. The actual values versus budgeted values percent of error is worse than all of the forecasted models. Holt's linear method performs substantially better than the budgeted figures except during FY01. The models would have predicted a figure closer to the actual numbers for the collective period from FY97-FY02. The negative percentages in Table 113 indicate estimates that are over-budget when compared with the actual numbers. Positive percentages indicate estimates that are under-budget when compared with the actual numbers.

Table 113. UH-3H Actual, Budgeted, Forecast Comparison

FY00	Budgeted	Actual	MA3 Forecast	SES Forecast	Holt's LM Forecast
	$ 1,824.61	$ 2,465.64	$ 1,812.39	$ 2,051.83	$ 2,528.30
Actuals vs. Budgeted	26.00%				
Actuals vs. Forecast			26.49%	16.78%	-2.54%
FY01	**Budgeted**	**Actual**	**3YMA Forecast**	**SES Forecast**	**Holt's LM Forecast**
	$ 2,196.59	$ 2,340.39	$ 2,137.97	$ 2,465.64	$ 2,820.85
Actuals vs. Budgeted	6.14%				
Actuals vs. Forecast			8.65%	-5.35%	-20.53%
FY02	**Budgeted**	**Actual**	**3YMA Forecast**	**SES Forecast**	**Holt's LM Forecast**
	$ 2,723.51	$ 2,792.56	$ 2,285.95	$ 2,340.39	$ 2,792.56
Actuals vs. Budgeted	2.47%				
Actuals vs. Forecast			18.14%	16.19%	0.00%

Best Model Results

Comparison of Actual, Forecasted, and Budgeted Data.

Graphs showing trends for the forecasted models are illustrated in Figures 60 through 65. The best models have trend lines closely following actual trended data. For example, if Holt's linear model is a good predictor of future results, the trend line should not deviate much from the actual results. The actual numbers are derived from the VAMOSC CES components 2.1, 2.2, and 2.3. Discrepancies across the services exist relating to how CPFH is calculated. CES components 2.1, 2.2, and 2.3 are used to calculate CPFH in this research. These CES components consist of the costs associated with fuel, DLRs, and consumable materials/repair parts. Only three years worth of data is presented due to the availability of the data in VAMOSC.

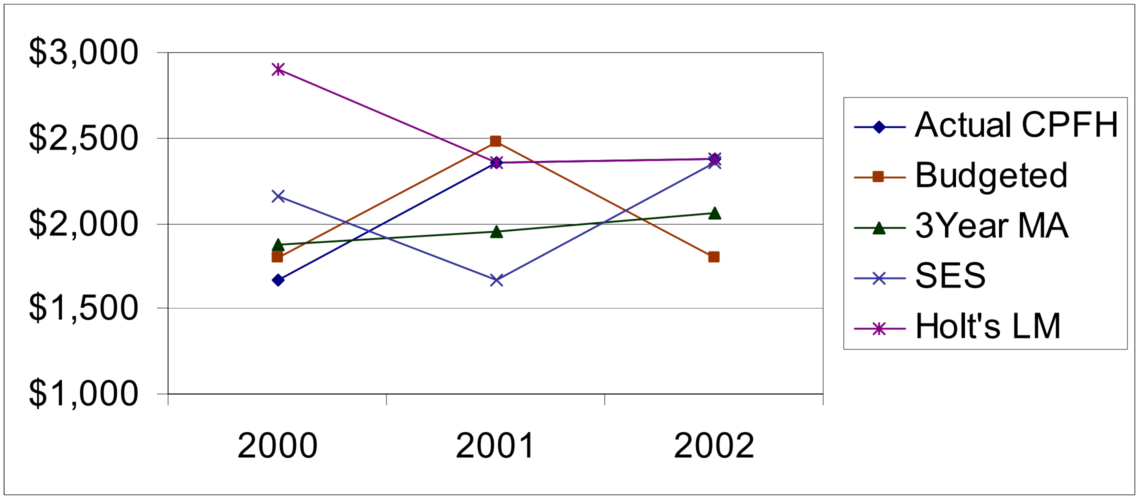

Figure 60. CH-46D Forecast Results

The results for Figure 60 are shown above. The best forecasted model is the MA3 model. The budgeted numbers from FY00 through FY02 actually have the lowest percent deviation when compared to the actuals against the forecasting models. The budgeted numbers follow the actuals closely except for FY02. Holt's linear method forecasts values more accurately during the last two years in comparison to the other models. However, Holt's linear model significantly deviates from the actual numbers during FY00. Consequently, the extreme deviation from FY00 actuals negates the low deviations during the subsequent years. The extreme deviation from FY00 actuals may be caused by the initialization process.

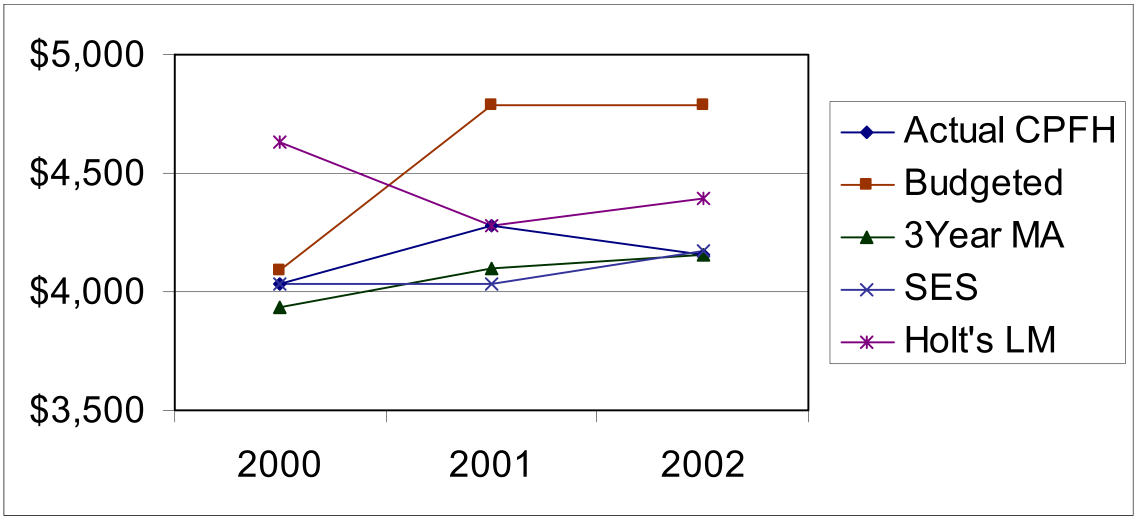

Figure 61. CH-53D Forecast Results

The results for Figure 61 are shown above. The SES model forecasts values closer to the actual numbers than the other forecasting methods. The SES trends upward because of the increasing trend from FY00 to FY01. The budgeted numbers are initially close but deviate significantly for the remaining two years. Holt's linear method deviates significantly from the actuals during the first year. Again, the initialization process may cause this deviation. Due to the limited amount of historical data, FY00 must be included in the forecasting models.

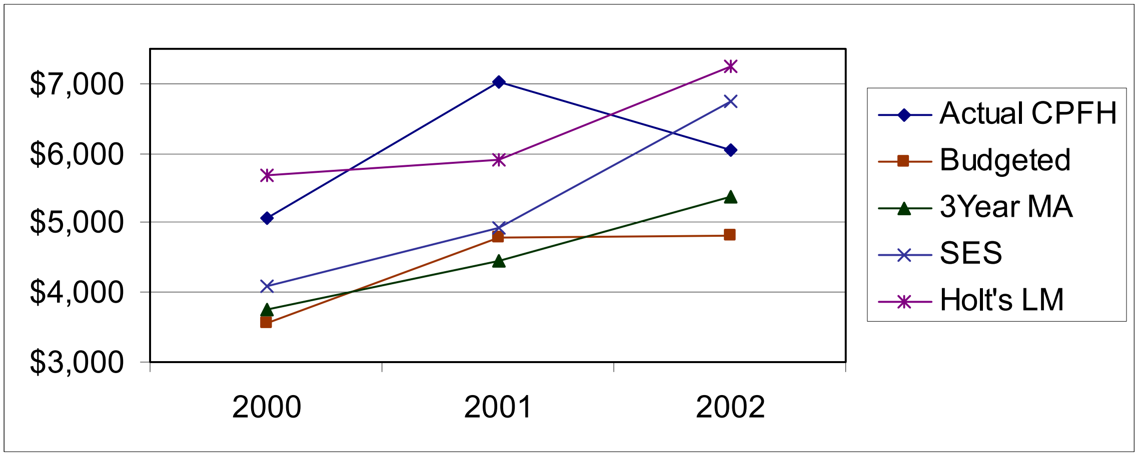

Figure 62. MH-53E Forecast Results

The best forecasting model for the MH-53E is the SES model (as shown in Figure 62). ME, MAE, MPE, and MAPE have been the determining criteria for deciding the best model, so far. SES calculates the forecast during the current period by adjusting the forecast error for the previous period. Since the actual data trends significantly upward from FY00 to FY01, the SES trends significantly upward in FY02. Initially, the SES forecast figures were well below the actuals. The adjustment brought the forecast in line with the actual trend because the actual trend decreased slightly. The budgeted numbers are significantly worse when compared with the other forecasting methods. Holt's linear method reacts to the upward trend in the data during the first two years and subsequently increases the following year. The actual value falls during FY02. Holt's linear method does not account for the fall because of the initial upward trend.

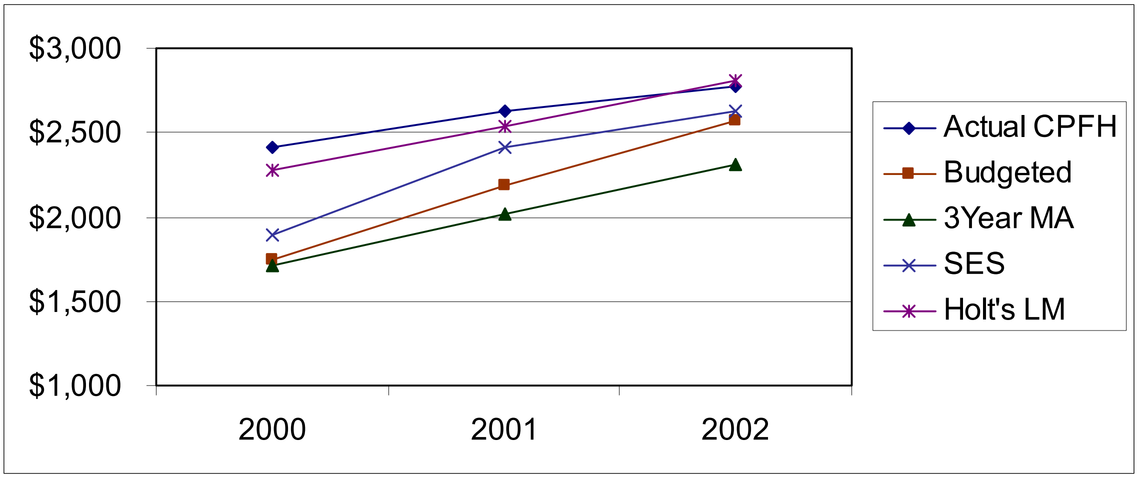

Figure 63. SH-60F Forecast Results

The best forecasting method for the SH-60F is Holt's linear method. In Figure 63, the actual values trend up each year. Holt's linear method takes into account the trended data and adjusts accordingly. Holt's linear method seems to work best for data that exhibit an overall trend. If the data increases and decreases with no apparent pattern, Holt's linear method does not work as well. In this case, Holt's linear method minimizes the absolute deviations from the actual data.

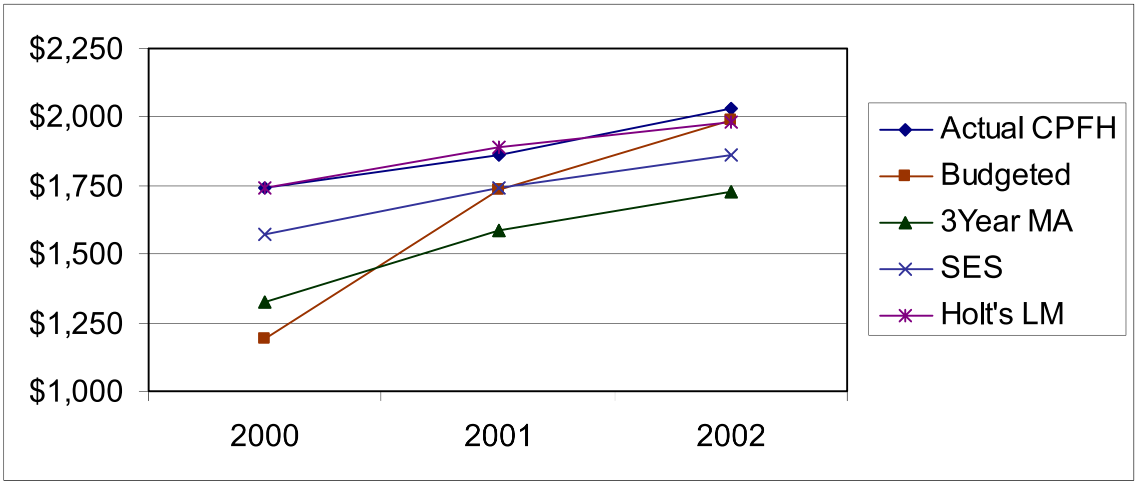

Figure 64. UH-1N Forecast Results

The results from the SH-60F and the UH-1N are similar. The actual CPFH data trends upward each year. The best forecasting model is Holt's linear method. Holt's linear method accounts for the upward trend in the actual data. Figure 63 and Figure 64 appear similar in terms of forecast model performance.

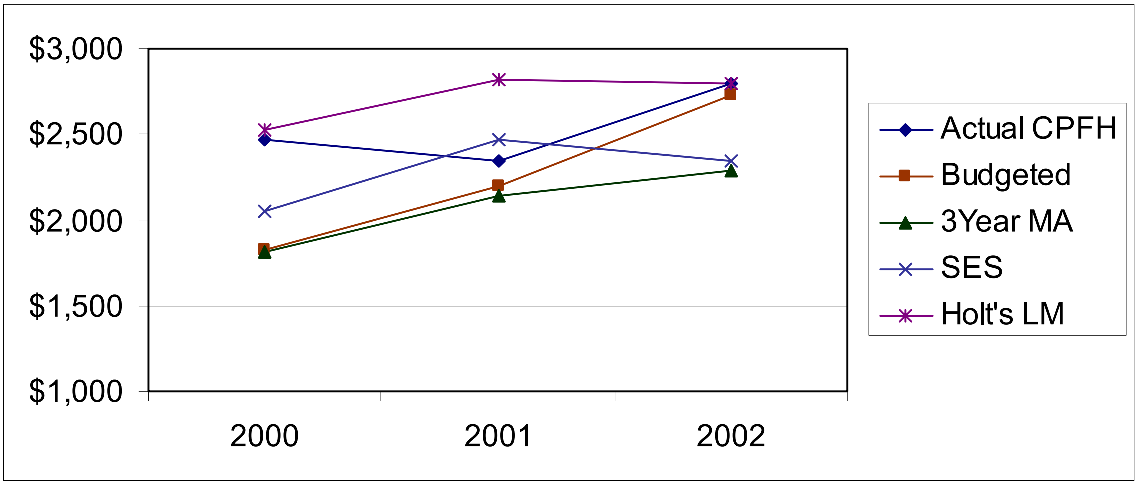

Figure 65. UH-3H Forecast Results

The results from Figure 65 are shown above. Holt's linear method is the best forecasting model. The absolute deviations are lower for this method when compared to the absolute deviations for other methods. The costs associated with flying hours are broken into a CPFH dollar figure. Costs for FY00 through FY02 are forecasted according to the different methods used. Now, the summary statistics are used to determine an overall best method to use in forecasting values for FY04.

The summary statistics and results for the forecasting methods are shown in Table 114. Table 114 ranks the models in order of the lowest MAPE. The basis for selecting the best overall model is not necessarily the method with the lowest MAPE. Theil's U is used to compare the methods to a naïve forecast. The model that consistently shows the best summary statistics and Theil's U calculations is deemed the best model.

Table 114. Forecasting Model Final Results

MAPE From Forecasting Model					
Rotary Aircraft	**Budgeted**	**MA3**	**SES**	**Holt's LM**	**Best Forecast**
CH-46D	12.52%	14.37%	16.52%	24.63%	**CH-46D**
CH-46D Rank Order	**1**	**2**	**3**	**4**	**Budgeted**
CH-53D	9.57%	2.23%	1.52%	8.06%	**CH-53D**
CH-53D Rank Order	**4**	**2**	**1**	**3**	**SES**
MH-53E	27.39%	24.33%	15.12%	21.00%	**MH-53E**
MH-53E Rank Order	**4**	**3**	**1**	**2**	**SES**
SH-60F	17.37%	22.99%	10.65%	4.09%	**SH-60F**
SH-60F Rank Order	**3**	**4**	**2**	**1**	**Holt's LM**
UH-1N	13.46%	17.89%	8.17%	6.73%	**UH-1N**
UH-1N Rank Order	**3**	**4**	**2**	**1**	**Holt's LM**
UH-3H	11.54%	17.76%	11.47%	8.84%	**UH-3H**
UH-3H Rank Order	**3**	**4**	**2**	**1**	**Holt's LM**

Holt's linear method is selected as the best forecasting method in terms of consistently having the lowest MAPE. The MAPE for Holt's linear method is the lowest in three of the six rotary aircraft. It is also intuitively appealing to select Holt's linear method for use in forecasting future values for rotary aircraft CPFH. The majority of the aircraft exhibit increasing CPFH values over time. In order to capture increasing or decreasing trends in data, an appropriate forecasting method must be used to account for the trends. Therefore, Holt's linear method should be used to capture any existing trends.

Theil's U.

When selecting a forecasting method to use, it is important to decide if the forecasting method will perform better than a naïve forecast. Naïve forecasts require relatively no effort in prediction. Naïve forecasts are based solely on the most recent information available (24:607). In other words, does the forecasting method provide a better prediction than using the most recent observation as the forecasted value for the next period? Theil’s U provides the comparison between the forecasting technique used and a naïve forecast of the most recent data. Chapter III explains the benefits of incorporating Theil’s U into the decision-making process.

Tables 115 through 120 show the results of using Theil’s U to compare each forecasting method to a naïve forecast for each helicopter. A Theil’s U value of less than

Table 115. Theil’s U CH-46D Calculation

CH-46D	Yt	Ft			Ft			Ft		
Period	CPFH	MA3	Numerator	Denominator	SES	Numerator	Denominator	Holt's LM	Numerator	Denominator
1	$1,408					0.2048409	0.204840892		0	0.204840892
2	$2,045				$1,408	0.0033072	0.003307233	$2,045	0.06455035	0.003307233
3	$2,162		0.0093887	0.053527583	$2,045	0.0535276	0.053527583	$2,682	0.3276764	0.053527583
4	$1,662	$1,871	0.0581839	0.174971926	$2,162	0.1749719	0.174971926	$2,900	6.2047E-16	0.174971926
5	$2,357	$1,956	0.0186157	0.000111561	$1,662	0.0001116	0.000111561	$2,357	3.7259E-11	0.000111561
6	$2,382	$2,060			$2,357			$2,382		
Total			0.0861883	0.228611071		0.4367592	0.436759196		0.39222676	0.436759196
		Theil's U	0.6140101		Theil's U	1		Theil's U	0.94764915	

Table 116. Theil’s U CH-53D Calculation

CH-53D	Yt	Ft			Ft			Ft		
Period	CPFH	MA3	Numerator	Denominator	SES	Numerator	Denominator	Holt's LM	Numerator	Denominator
1	$3,537					0.02476626	0.024766261		0	0.024766261
2	$4,094				$3,537	0.00611749	0.000354895	$4,094	0.01372076	0.000354895
3	$4,171		0.00054249	0.001123742	$3,851	3.8643E-18	0.001123742	$4,650	0.02082929	0.001123742
4	$4,031	$3,934	0.00191845	0.003665848	$4,031	0.00366585	0.003665848	$4,633	4.7195E-17	0.003665848
5	$4,275	$4,099	1.9446E-06	0.000815256	$4,031	1.3129E-05	0.000815256	$4,275	0.00318598	0.000815256
6	$4,153	$4,159			$4,169			$4,394		
Total			0.00246288	0.005604845		0.03456273	0.030726		0.03773603	0.030726
		Theil's U	0.66288787		Theil's U	1.06059843		Theil's U	1.10821774	

Table 117. Theil's U MH-53E Calculation

MH-53E	Yt	Ft			Ft			Ft		
Period	CPFH	MA3	Numerator	Denominator	SES	Numerator	Denominator	Holt's LM	Numerator	Denominator
1	$3,168					0.2263588	0.226358827		0	0.226358827
2	$4,675				$3,168	2.404E-14	0.005273433	$4,675	0.1560304	0.005273433
3	$4,335		0.0664407	0.037669519	$4,335	0.0376695	0.037669519	$6,182	1.214E-15	0.037669519
4	$5,177	$4,059	0.2026568	0.132258428	$4,335	0.1602288	0.132258428	$5,177	0.0727432	0.132258428
5	$7,060	$4,729	0.0063242	0.019043268	$4,987	0.0051665	0.019043268	$5,663	0.0773957	0.019043268
6	$6,085	$5,524			$6,593			$8,049		
Total			0.2754217	0.188971214		0.4294236	0.420603474		0.3061694	0.420603474
		Theil's U	1.2072611		Theil's U	1.0104307		Theil's U	0.8531874	

Table 118. Theil's U SH-60F Calculation

SH-60F	Yt	Ft			Ft			Ft		
Period	CPFH	MA3	Numerator	Denominator	SES	Numerator	Denominator	Holt's LM	Numerator	Denominator
1	$1,487					0.03131858	0.031318576		0	0.031318576
2	$1,750				$1,487	0.00704706	0.00704706	$1,750	0.00441086	0.00704706
3	$1,897		0.1374738	0.074477423	$1,750	0.07447742	0.074477423	$2,013	0.0053171	0.074477423
4	$2,415	$1,711	0.064166	0.008117847	$1,897	0.00811785	0.008117847	$2,276	0.00147518	0.008117847
5	$2,632	$2,021	0.0306763	0.002968784	$2,415	0.00296878	0.002968784	$2,539	0.00010504	0.002968784
6	$2,776	$2,315			$2,632			$2,803		
Total			0.2323161	0.085564054		0.12392969	0.12392969		0.01130817	0.12392969
		Theil's U	1.6477601		Theil's U	1		Theil's U	0.30207064	

Table 119. Theil's U UH-1N Calculation

UH-1N	Yt	Ft			Ft			Ft		
Period	CPFH	MA3	Numerator	Denominator	SES	Numerator	Denominator	Holt's LM	Numerator	Denominator
1	$955					0.2624548	0.262454769 -		0	0.262454769
2	$1,445				$955	0.00806	0.008059972	$1,445	0.0619909	0.008059972
3	$1,575		0.069649	0.01110355	$1,445	0.0111036	0.01110355	$1,934	5.754E-14	0.01110355
4	$1,741	$1,325	0.0245428	0.004660317	$1,575	0.0046603	0.004660317	$1,741	0.0002776	0.004660317
5	$1,859	$1,587	0.0273079	0.00863096	$1,741	0.008631	0.00863096	$1,888	0.0007524	0.00863096
6	$2,032	$1,725			$1,859			$1,981		
Total			0.1214997	0.024394827		0.2949096	0.294909568		0.0630209	0.294909568
		Theil's U	2.2317149		Theil's U	1		Theil's U	0.4622721	

Table 120. Theil's U UH-3H Calculation

UH-3H	Yt	Ft			Ft			Ft		
Period	CPFH	MA3	Numerator	Denominator	SES	Numerator	Denominator	Holt's LM	Numerator	Denominator
1	$1,489					0.0749189	0.074918915		0	0.074918915
2	$1,896				$1,489	0.0067135	0.006713488	$1,896	0.0176778	0.006713488
3	$2,052		0.1013618	0.040674755	$1,896	0.0406748	0.040674755	$2,304	0.0009327	0.040674755
4	$2,466	$1,812	0.0067399	0.002580411	$2,052	0.0025804	0.002580411	$2,528	0.03797	0.002580411
5	$2,340	$2,138	0.0468564	0.037327431	$2,466	0.0373274	0.037327431	$2,821	8.242E-16	0.037327431
6	$2,793	$2,286			$2,340			$2,793		
Total			0.1549581	0.080582597		0.162215	0.162215		0.0565805	0.162215
		Theil's U	1.3867126		Theil's U	1		Theil's U	0.5905925	

1.0 indicates that the forecasting method is better than the naïve forecast. A Theil's U value equal to 1.0 results in a decision that the forecasting technique in question works no better than the naïve forecast. A Theil's U value greater than 1.0 proves that the forecasting technique is actually worse than the naïve forecast.

In Table 115 the MA3 method has the lowest Theil's U value. In Table 116, the only method that results in a Theil's U value less than 1.0 is the MA3 method. The CH-46D does in fact have the lowest summary statistics when the MA3 method is used to forecast future values. The results for the CH-53D are mixed. The MA3 method is the only model resulting in a Theil's U value of less than 1.0, however, the SES method produced the lowest summary statistics. Holt's linear method possesses the best Theil's U values for the remainder of the helicopters. If an overall method is desired for use in future prediction, Holt's linear method clearly out-performs the competing models. Holt's linear method beats the naïve forecast in five out of six helicopters. Holt's linear method consistently beats the budgeted forecasts for FY00-FY02. The SES method does no better than the naïve forecast in prediction of future CPFH when using Theil's U as the determining factor in model selection.

FY04 Forecast Results

The preceding sections look at CES component and CPFH trends for FY97-FY02. Based on historical data from this period, three methods were utilized to develop models for forecasting future data. The purpose of this endeavor is to give the OSD/CAIG a useful tool to gauge future submissions of CPFH data for rotary aircraft. The forecasting methods were compared with each other, with the actual data, and with budgeted data submitted by the services. Holt's linear method is the preferred model for forecasting figures for FY04. This section is presents the results for the forecasts by helicopter for FY04.

The best model was evaluated according to the summary statistics presented in Chapter III. Useful indicators of model success, such as MAPE and Theil's U, were calculated and each model was screened to determine the course of action for forecasting FY04 data. Holt's linear method has the best Theil's U value in two-thirds of the rotary aircraft examined. Therefore, Holt's linear method is used to forecast all of the numbers for FY04.

The FY03 CPFH data was made available by VAMOSC personnel approximately a month before the data is to be released to the public. Portions of the data may not be finalized. The data is separated by CES sub-component. Table 121 shows SH-60F CPFH data and is representative of the format common to all of the rotary aircraft in this research. CES component costs are added and the sum is divided by the number of flying hours. The FY03 SH-60F CPFH is approximately $3,020.

Table 121. FY03 CPFH Data for the SH-60F

CES	Total
2.1 POL/Energy Consumables	$ 3,470,230
2.2 Consumable Materials/Repair Parts	$ 21,253,980
2.3 Depot Level Reparables	$ 57,680,067
Total Cost	$ 82,404,277
# of Flying Hours	27,284
Total Overall SH-60F CPFH	
$3,020.24	

The same method of calculating FY03 CPFH is conducted for the remaining rotary aircraft. The final figures are inserted into the models used previously to calculate all of the summary statistics. Solver is run again to evaluate the Holt's linear method model. Solver, again, minimizes MAPE based on the optimal values for alpha and beta. After the optimal solution is found, a forecasted value for FY04 is calculated. Table 122 shows the results for the SH-60F helicopter. Similar models, like Table 122, are run until a forecasted value is found for each helicopter.

Table 122. SH-60F FY04 Forecast Based on Holt's Linear Method

				α =	0.803	β =	0	m =	1
	Yt			Ft	Error	|Error|	(Error/Yt)*100		|(Error/Yt)|*100
Period	CPFH	Lt	bt	Holt's LM	Yt-Ft	|Yt-Ft|	Percent Error		Absolute Percent Error
1997	$1,487	$1,487	$263						
1998	$1,750	$1,750	$263	$1,750	$0	$0	0.00%		0.00%
1999	$1,897	$1,920	$263	$2,013	-$116	$116	-6.13%		6.13%
2000	$2,415	$2,369	$263	$2,183	$232	$232	9.59%		9.59%
2001	$2,632	$2,632	$263	$2,632	$0	$0	0.00%		0.00%
2002	$2,776	$2,799	$263	$2,895	-$120	$120	-4.31%		4.31%
2003	$3,020	$3,029	$263	$3,062	-$42	$42	-1.39%		1.39%
2004				$3,292					
Total					-$46	$510	-2.24%		21.43%
					ME	MAE	MPE		MAPE
					-$9	$102	-0.45%		4.29%

After Solver is re-run for the SH-60F model, the MAPE becomes 4.29%. The newly calculated MAPE is higher than the original MAPE calculated in the model (see Table 78) without the included FY03 actual data. In fact, the MAPE in the newly calculated models is worse than the original models in all but two. The MAPE for the MH-53E and UH-3H improved when Solver is run with the FY03 data included. Neither the increased or decreased change in MAPE is significantly different from the previously run models. The summary data, including the new FY03 data for all of the rotary aircraft, is presented in Table 123. Table 123 contains summary data after re-running

Solver. All of the summary statistics change after Solver is re-run. The new summary statistics are shown in Table 123. Additionally, the forecast for FY04, based on Holt's linear method, is included in bold text. The FY04 Forecast numbers should be used to budget for CPFH during FY04.

Table 123. Summary Table Including FY03 Data with FY04 Forecast

CH-46D Summary				
ME	**MAE**	**MPE**	**MAPE**	**FY04 Forecast**
-$285	$513	-18.09%	25.04%	**$3,440**
CH-53D Summary				
ME	**MAE**	**MPE**	**MAPE**	**FY04 Forecast**
-$99	$454	-3.29%	10.16%	**$5,516**
MH-53E Summary				
ME	**MAE**	**MPE**	**MAPE**	**FY04 Forcast**
-$916	$920	-18.34%	18.39%	**$8,696**
SH-60F Summary				
ME	**MAE**	**MPE**	**MAPE**	**FY04 Forecast**
-$9	$102	-0.45%	4.29%	**$3,292**
UH-1N Summary				
ME	**MAE**	**MPE**	**MAPE**	**FY04 Forecast**
$48	$205	-0.23%	9.59%	**$3,470**
UH-3H Summary				
ME	**MAE**	**MPE**	**MAPE**	**FY04 Forecast**
-$150	$171	-6.82%	7.47%	**$3,656**

Charts are added in Figures 66-71 to show the new trend lines after re-running Solver to include the FY03 data. Holt's linear method lines are extended one year to show the FY04 forecast. Holt's linear method works best for data showing upward trends. If any major shifts in historical data occur, a lag will exist in the forecast data. Holt's linear method accounts for trends and will lag the actual data if a shift in direction occurs. During FY97-FY02, the data generally trended upward with no major shifts or changes in direction.

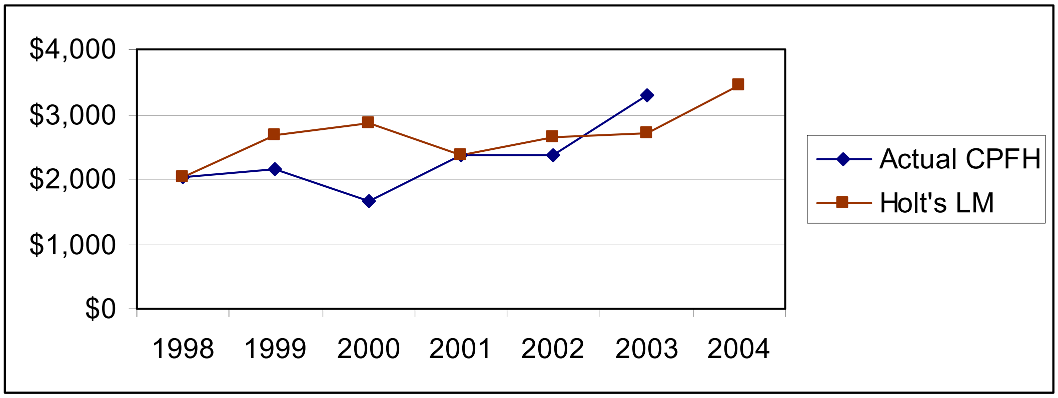

Figure 66. CH-46D Trend Chart (Accounting for FY03)

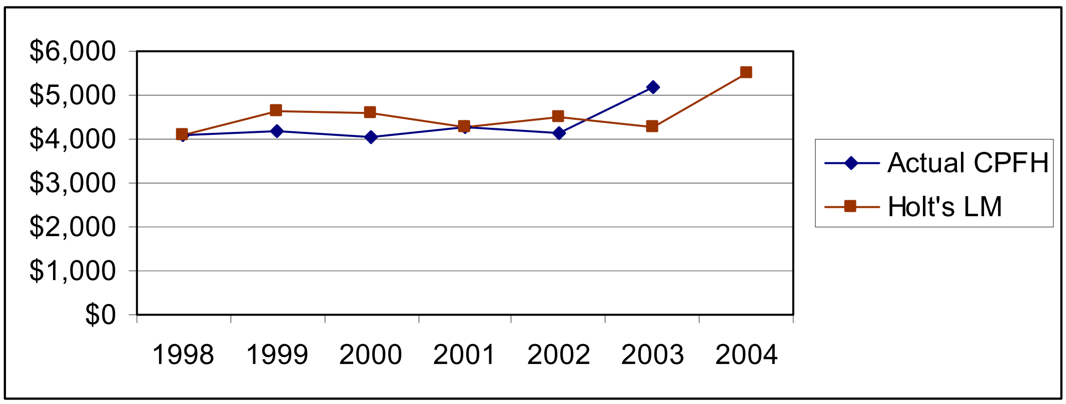

Figure 67. CH-53D Trend Chart (Accounting for FY03)

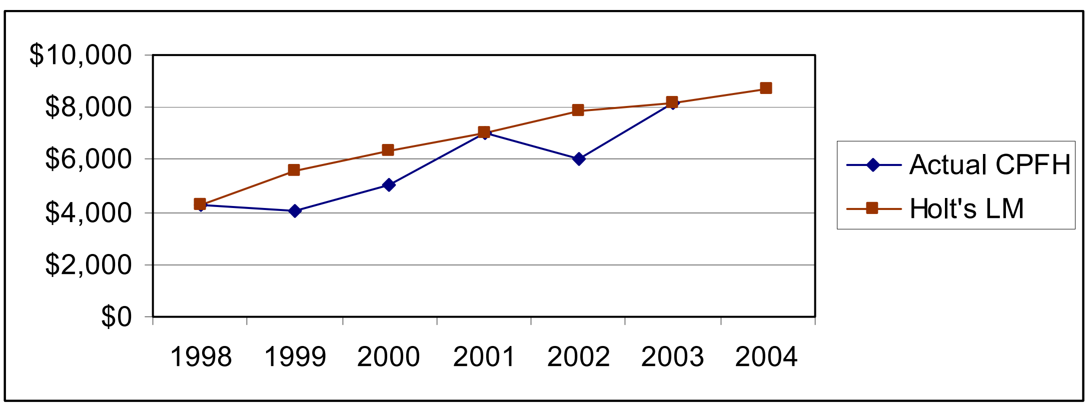

Figure 68. MH-53E Trend Chart (Accounting for FY03)

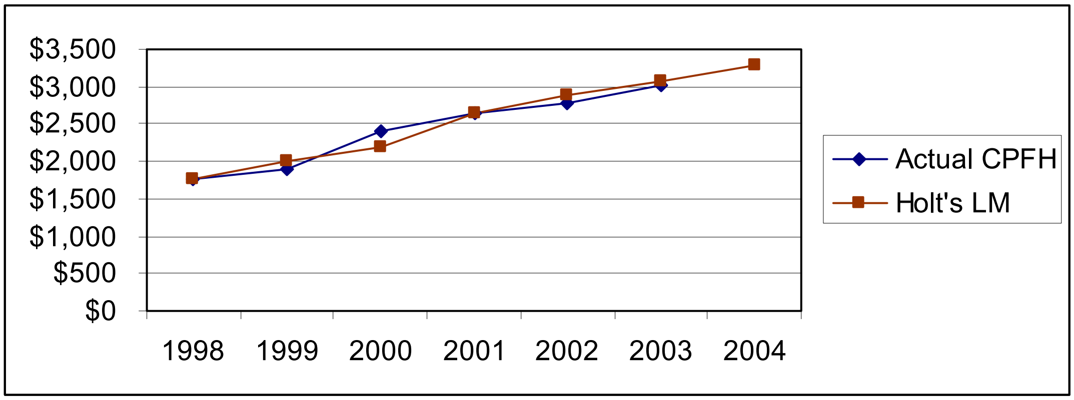

Figure 69. SH-60F Trend Chart (Accounting for FY03)

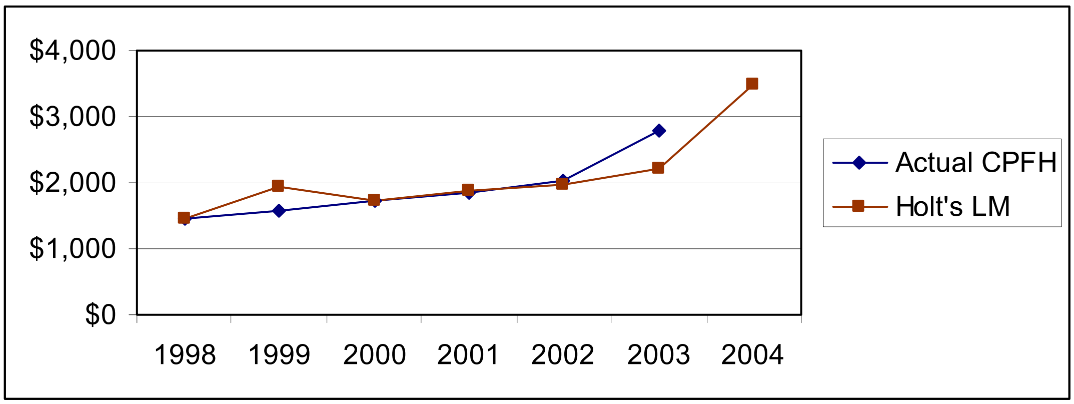

Figure 70. UH-1N Trend Chart (Accounting for FY03)

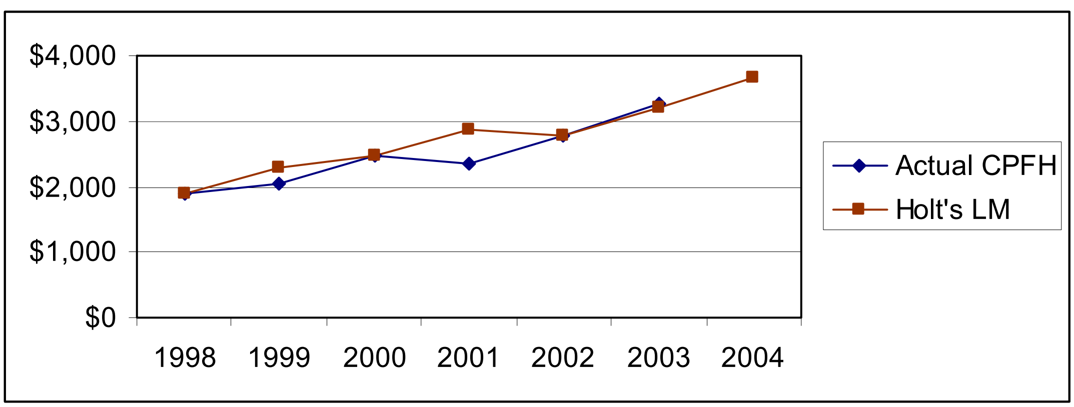

Figure 71. UH-3H Trend Chart (Accounting for FY03)

Chapter Summary

Chapter IV incorporates all of the equations in Chapter III to develop forecasting models. Three methods are utilized for each rotary aircraft. The methods include the MA3, SES, and Holt's linear method. After running Solver, summary statistics provide the means by which the model selection process can begin. Key summary statistics for this research include MAPE and Theil's U. Holt's linear method is selected, as it proves to be the most consistent method in providing the best summary statistics.

For FY00-FY02, all three forecasting methods perform better than the budgeted numbers when percent deviation is calculated versus actuals for all rotary aircraft, except one. The superior performance demonstrated by forecasted versus actuals compared to budgeted versus actuals, supports the notion that any of the three forecasting methods will produce improved results. Theil's U values suggest Holt's linear method is overwhelmingly better than the naïve forecast in four out of six helicopters. The OSD/CAIG can use Holt's linear method to forecast future values for the rotary aircraft studied during this research. Holt's linear method is a great forecasting method to employ when upward continuing trends exist, such as the increasing CPFH and O&S trends discussed in Chapter IV.

V. Conclusion

Problem Revisited

Operating and Support (O&S) costs constitute the majority of the total life cycle cost for Air Force weapons systems. The first step in being able to control these costs is to understand the elements that comprise these costs and the proportion each element contributes to the total cost. The understanding of the nature of these costs will lead to more accurate budget submissions and better fiscal responsibility. The discrepancy between budget submissions and actual expenditures for cost per flying hour (CPFH) programs lends itself to the need for the research conducted within this thesis. The primary objective of this research was to provide Office of the Secretary of Defense/Cost Analysis Improvement Group (OSD/CAIG) with a useful tool to forecast CPFH for Navy rotary aircraft. These forecasts would then be used by the OSD/CAIG to analyze both the budget submissions of the Air Force and the independent cost estimates of the OSD/CAIG.

Limitations

The spreadsheets developed in this research are useful for forecasting costs. The spreadsheets do need routine maintenance and call for additional analysis as new data is added. The forecasts that were developed for each helicopter cannot simply be extended as the next fiscal year's data becomes available. In order maintain consistency with the methodology used and described in Chapter III to provide the most accurate forecast possible, the formulas and calculations need adjustment. As data is added to each time series, the applicable alpha and beta levels of each forecast must be re-calculated. After the adjustments are made, all three forecasting methods can be extended one period and then re-evaluated using the four evaluation measures also described in Chapter III. Also, as new data becomes available it will be necessary to evaluate the time series to ensure that all of the data being used is still relevant when forecasting for the next period. It is possible that a change in CPFH reporting procedures could produce a cost level shift that could cause prior years data to become irrelevant when trying to predict the future costs.

Summary of Literature Review

The literature review begins by explaining how O&S costs have become an important issue within the Department of Defense (DoD). It then describes the DoD initiatives to control escalating costs. The rest of the literature review is broken down into two major categories: Major O&S Guidance, and Past Research. The first part of the Major O&S Guidance section gives a brief description of the six helicopters studied. Next, the section gives an overview of Title 10 that establishes the legal requirement for O&S cost estimating and reporting. The section also provides an overview of the DoD directives and guidance that tailor O&S cost estimating and reporting to the specific needs of the DoD. The section continues by explaining the establishment of the Visibility and Management of Operating and Support Costs (VAMOSC) system. The Past Research section includes the details and results of four other theses and four professional reports that directly relate to the material of this research. This section contains studies of CPFH and O&S cost reduction from the Army, Navy, and the Air Force. Although none of the literature of this section is an exact match of the research of this thesis, it does provide a solid background and show the necessity of the research contained within this thesis.

Review of the Methodology

The methodology of this research begins with a description of the VAMOSC database and describes the data extraction and sorting process for the empirical O&S and CPFH break-out portion of the research. The methodology also describes the formulas used to evaluate the actual CPFH against the budget submissions for FY00-FY02, and the actual CPFH against the forecasted figures for FY00-FY02. The methodology thoroughly describes each of the three forecasting methods being employed within this research and provides in depth detail of the four evaluation measures being utilized to determine the overall best forecasting method for each time series. The significance of Theil's U in comparison to the naïve forecast is discussed and put in practice in Chapter IV. The methodology concludes with an explanation of forecasting for FY04, the final step in this research.

Restatement of Results

The CH-46D O&S CPFH fluctuate up and down during the period studied. There is no apparent increasing or decreasing trend in the data. There are trends within two elements of the cost element structure (CES). Unit-Level Consumption dramatically increases by 27 percent while Mission Personnel decreases by 13 percent. Depot-level reparables (DLRs) and consumables constitute the majority of CPFH. CPFH increases steadily during the period studied. The three-year moving average (MA3) method produced the best summary statistics and Theil's U value. The absolute percent deviations for the forecasted versus actual data were higher than the absolute percent deviations for the budgeted versus actual data. Therefore, in terms of percent error, the budgeted numbers were better predictors of actual cost than the forecasted numbers were. In all of the other helicopters, the forecasted data provided better results that were closer to the actual data.

For the CH-53D, the total O&S cost attributed to CPFH decreases somewhat from FY97-FY02. Intermediate Maintenance has decreased approximately ten percent over time while Mission Personnel and Unit-Level Consumption have slightly increased. CPFH costs trend upward. The single exponential smoothing (SES) method demonstrates the best mean absolute percent error (MAPE) but not the best Theil's U value. The MA3 method has a slightly higher MAPE but was the only method that possesses a Theil's U value lower than 1.0. Therefore, the best method selected for this individual helicopter is the MA3 method. When compared to the budgeted data, all of the forecasting methods perform better when looking at absolute percent deviation.

The MH-53E O&S CPFH trends upward except for a dip in FY02. Sustaining Support decreases approximately 11 percent while Unit-Level Consumption steadily increases the first few years and levels off in FY00. CPFH costs increase almost every year. The SES method exhibited the best summary statistics but not the best Theil's U value. Holt' linear method is the only method that has a Theil's U value lower than 1.0. All of the forecasting methods, when compared with the actual numbers, produce lower absolute percent errors than the budgeted figures.

The SH-60F O&S CPFH generally trends upward. Unit-Level Consumption increases almost ten percent over the period studied. CPFH increases every year during FY97-FY02. With a MAPE of 4.09%, Holt's linear model out-performs MA3 and SES. Additionally, all of the summary statistics are better for the Holt's linear method model when compared with the other models. Holt's linear method possesses the best Theil's U value. The SES method and Holt's linear method, when compared with the actual numbers, produce lower absolute percent errors than the budgeted figures.

The UH-1N O&S CPFH generally trends upward. Mission Personnel and Unit-Level Consumption substantially increase during the period studied. UH-1N CPFH increases every year during FY97-FY02. With a MAPE of 6.73%, Holt's linear method out-performs MA3 and SES. Additionally, all of the summary statistics are better for the Holt's linear method model when compared with the other models. Holt's linear method works particularly well for the UH-1N and the SH-60F the data sets because the costs trend upward every year. When examining absolute percent deviation to the actuals, SES and Holt's linear method perform substantially better than the budgeted figures. Additionally, Holt's linear method owns the best Theil's U value out of the three methods studied.

Overall costs, as well as O&S costs attributed to CPFH for the UH-3H, steadily increase over time. Mission Personnel notably decreases during the period almost 14 percent. Depot Maintenance increases approximately 13 percent. UH-3H CPFH increases almost every year during the period studied. With a MAPE of 8.84%, Holt's linear method out-performs MA3 and SES. Additionally, the majority of the summary statistics are better for the Holt's linear method model when compared with the other models. Additionally, Holt's linear method has the lowest Theil's U value. Holt's linear method, when compared with the actual numbers, produces lower absolute percent errors than the budgeted figures.

Recommendations

After examining each forecasting method for all of the helicopters studied, Holt's linear method is the best overall forecasting method to use when predicting future costs. Holt's linear method exhibits the best summary statistics in three out of the six helicopters studied. Holt's linear method displays the lowest MAPE for the SH-60F, the UH-1N, and the UH-3H. Additionally, Holt's linear method had the lowest Theil's U value for four out of the six helicopters studied. Holt's linear method is the only method to have a Theil's U value lower than 1.0 for the MH-53E, the SH-60F, the UH-1N, and the UH-3H. Because of the superior results when compared to the other methods, Holt's linear method should be used to forecast costs for the upcoming year (in this case, FY04).

In the case of the CH-46D and CH-53D helicopters, Holt's linear method should not necessarily be the method of choice. The final FY04 forecasts for these two helicopters were produced with Holt's linear method. However, Holt's linear method did not manufacture the best summary statistics. The MA3 method is the only forecasting method to generate a Theil's U value less than 1.0 for the CH-53D. Therefore, the FY04 forecast for the CH-46D and CH-53D helicopters could be created with the MA3 method instead of Holt's linear method. Holt's linear method is deemed the overall best method for the aforementioned reasons and applied to all models when forecasting a value for FY04.

Holt's linear method is, perhaps, the best method for the type of forecasting used to predict CPFH. During the period studied, CPFH generally trends upward over the course of time. If more periods of data are added to the study, some of the fluctuations in cost data will be smoothed out over time. The costs will steadily increase unless something is done to control costs. Holt's linear method is preferred in a situation where an increasing or decreasing trend exists. The method should only be employed in inherently trendy environments such as the O&S CPFH environment.

Possible Follow-On Theses

The research of this thesis only touches a very small portion of several important and interesting topics. There are many more areas the Navy could employ forecasting, and the efforts to realize O&S cost savings will be debated for a long time. This research sheds light on other opportunities for study. Here are some suggestions:

- Apply this same analysis and forecasting methodology to other Navy platforms, such as: fighter, bomber, or cargo aircraft.
- Explore other forecasting techniques that could be used to determine CPFH factors for Navy aircraft.
- Analyze the method used to allocate costs within the VAMOSC database.
- Repeat this research on the same helicopters as FY04-FY06 data becomes available.
- Analyze the CPFH figures forecasted for FY04 to the actual CPFH for FY04 and determine reasons for any disconnects that are present.
- Determine useful applications of forecasting techniques in budgeting for other Navy costs.
- Create a program that will apply the methodology of this thesis to a time series to forecast other CPFH factors.

- Explore the effects of deployments on total O&S costs.

- Analyze the different methodologies used by each service in determining CPFH factors and determine if better methods are available.

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Vita

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